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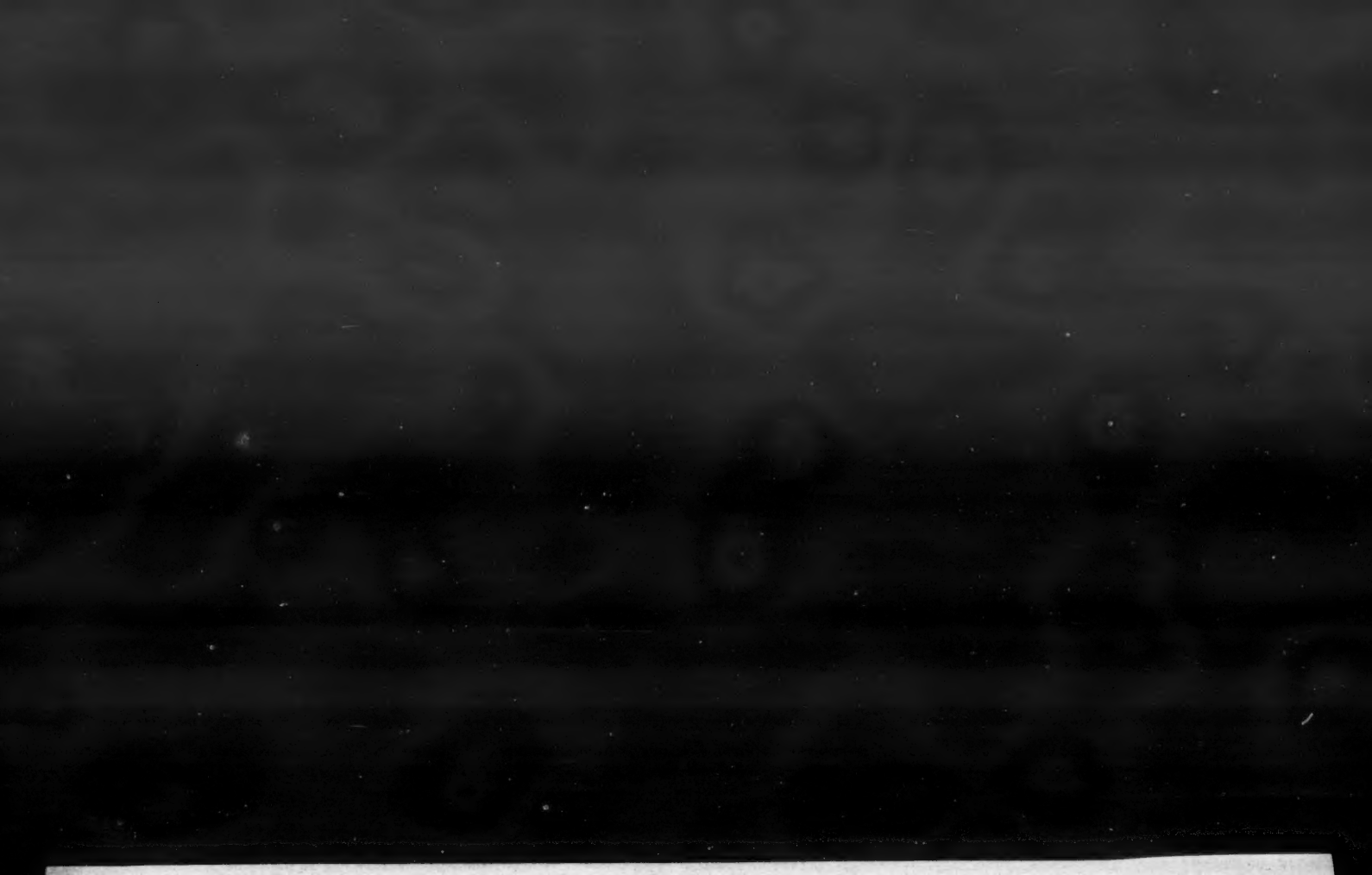
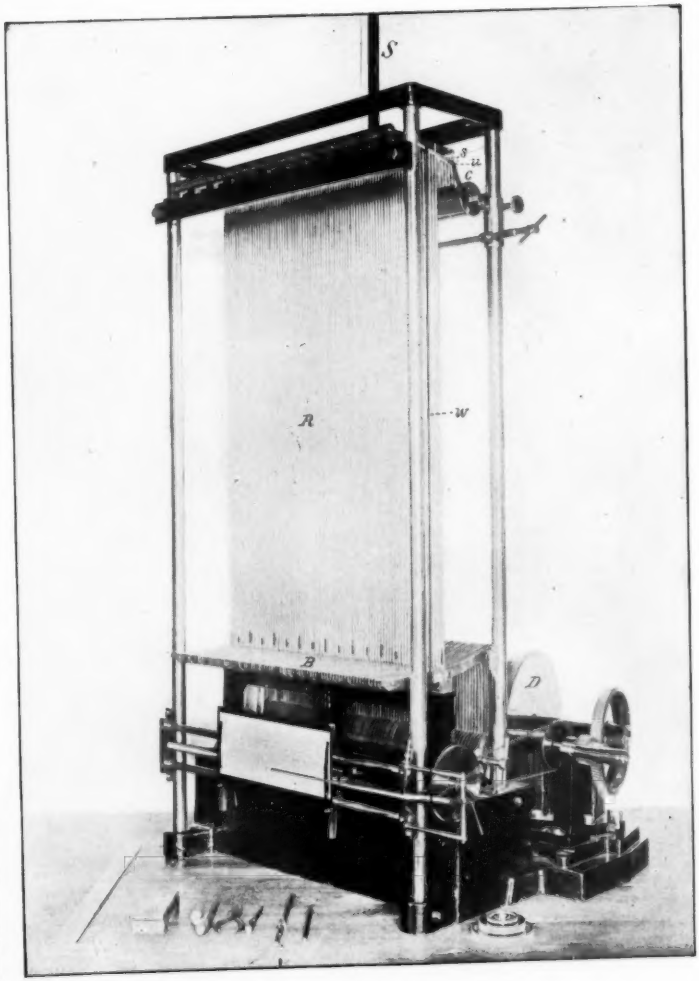




A NEW HARMONIC ANALYZER.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. I.—*A new Harmonic Analyzer;* by A. A. MICHELSON and S. W. STRATTON. (With Plate I.)

EVERY one who has had occasion to calculate or to construct graphically the resultant of a large number of simple harmonic motions has felt the need of some simple and fairly accurate machine which would save the considerable time and labor involved in such computations.

The principal difficulty in the realization of such a machine lies in the accumulation of errors involved in the process of addition. The only practical instrument which has yet been devised for effecting this addition is that of Lord Kelvin. In this instrument a flexible cord passes over a number of fixed and movable pulleys. If one end of the cord is fixed, the motion of the other end is equal to twice the sum of the motions of the movable pulleys. The range of the machine is however limited to a small number of elements on account of the stretch of the cord and its imperfect flexibility, so that with a considerable increase in the number of elements the accumulated errors due to these causes would soon neutralize the advantages of the increased number of terms in the series.

It occurred to one of us some years ago that the quantity to be operated upon might be varied almost indefinitely, and that most of the imperfections in existing machines might be practically eliminated. Among the methods which appeared most promising were addition of fluid pressures, elastic and other forces, and electric currents. Of these the simplest in practice is doubtless the addition of the forces of spiral springs.

The principle upon which the use of springs depends may be demonstrated as follows:

Let a (Fig. 1)=lever arm of small springs, s. (but one of which is shown in the fig.)
b=lever arm of large counter-spring, S.
$l_\circ$=natural length of small springs.
$L_\circ$=natural length of large springs.
$l+x$=stretched length of small springs.
$L+y$=stretched length of large springs.
e=constant of small springs.
E=constant of large springs.
n=number of small springs.
p=force due to one of the small springs.
P=force due to the large spring.

then
$$p=\frac{e}{l_\circ}\left(l+x-\frac{a}{b}y\right)$$
$$P=\frac{E}{L_\circ}(L+y)$$
$$a\Sigma p=bP.$$

whence
$$y=\frac{\Sigma x}{n\left(\frac{l}{L}+\frac{a}{b}\right)}$$

From this it follows that the resultant motion is proportional to the algebraic sum of the components, at least to the same order of accuracy as the increment of force of every spring is proportional to the increment of length.

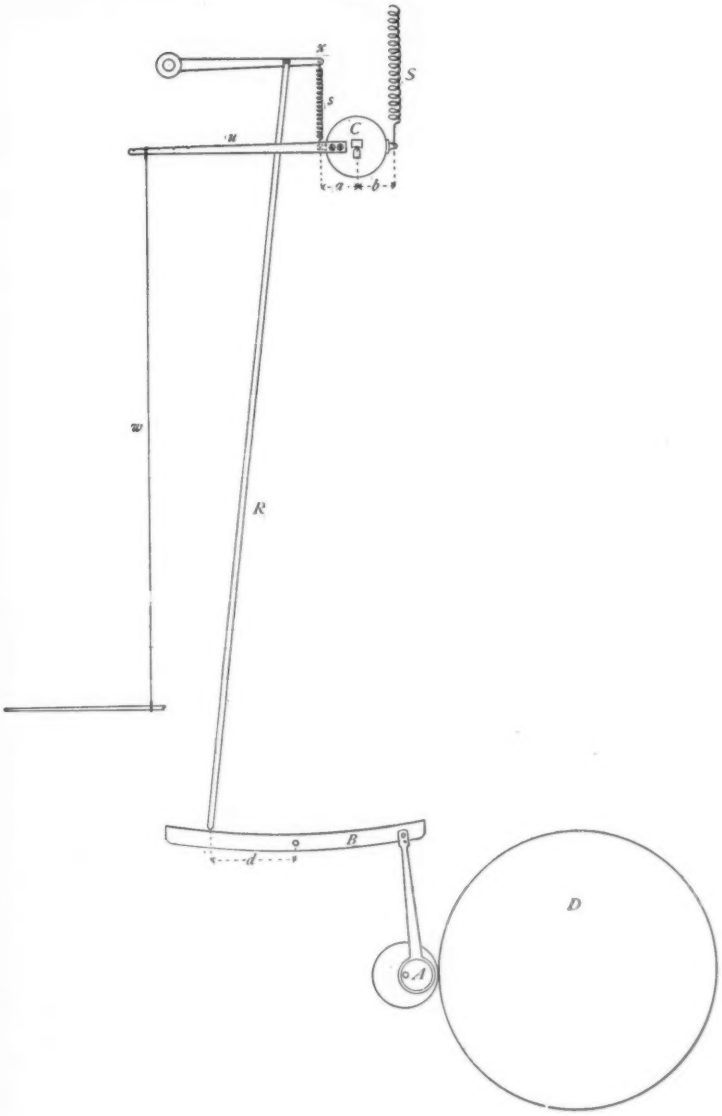
To obtain the greatest amplitude for a given number of elements, the ratios $\frac{l}{L}$ and $\frac{a}{b}$ should be as small as possible, but of course a limit is soon reached, when other considerations enter.

About a year ago a machine was constructed on this principle with twenty elements and the results obtained* were so encouraging that it was decided to apply to the Bache Fund for assistance in building the present machine of eighty elements.

Fig. 1 shows the essential parts of a single element. s is one of eighty small springs attached side by side to the lever C, which for greater rigidity has the form of a hollow cylinder, pivoted on knife edges at its axis. S is the large counter-spring. The harmonic motion produced by the excentric A, is communicated to x by the rod R and lever B, the amplitude of the motion at x depending on the adjustable distance d.

* Paper read before the National Academy of Science, April, 1897.

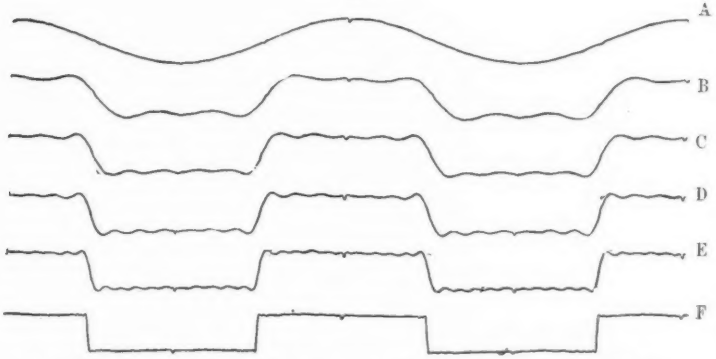
1.



The resultant motion is recorded by a pen connected with u by a fine wire w. Under the pen a slide moves with a speed proportional to the angular motion of the cone D. (Plate I.)

To represent the succession of terms of a Fourier series the excentrics have periods increasing in regular succession from one to eighty. This is accomplished by gearing to each excentric a wheel, the number of whose teeth is in the proper ratio. These last are all fastened together on the same axis and form the cone D. (Plate I.)

2.



A, one term; B, five terms; C, nine terms; D, thirteen terms; E, twenty one terms; F, seventy-nine terms.

Turning the cone will produce at the points (x) motions corresponding to $\cos\theta$, $\cos 2\theta$, $\cos 3\theta$, etc., up to $\cos 80\theta$, and whose amplitudes depend on the distances d. The motion of the elements may also be changed from sine to cosine by disengaging the cone and turning all of the excentrics through 90° by means of a long pinion which can be thrown in gear with all of the excentric wheels at once.

The efficiency and accuracy of the machine is well illustrated in the summation of Fourier series shown in the accompanying figures.

Figure 2 shows the dependence of the accuracy of a particular function on the number of terms of the series. Figures 3, 4, 5, 6 and 7 are illustrations of a number of standard forms, and 8, 9 and 10 illustrate the use of the machine in constructing curves representing functions which scarcely admit of other analytical expression.

The machine is capable not only of summing up any given trigonometrical series but can also perform the inverse process

3.

$\cos x + \frac{1}{3^2}\cos 3x + \frac{1}{5^2}\cos 5x +$

$\cos 4x + \frac{1}{3^2}\cos 12x + \frac{1}{5^2}\cos 20x +$

$\sin x - \frac{1}{3^2}\sin 3x + \frac{1}{5^2}\sin 5x -$

4.

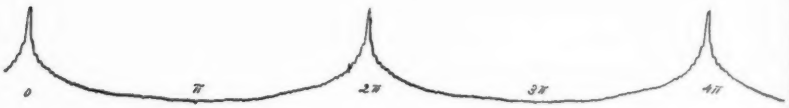
$\sin x + \frac{1}{3}\sin 3x + \frac{1}{5}\sin 5x +$

$\sin x + \frac{1}{2}\sin 2x + \frac{1}{3}\sin 3x +$

$-\cos 4x - \frac{1}{3}\cos 12x + \frac{1}{5}\cos 20x -$

$\sum_1^{\infty}\left(\sin\frac{1}{2}n\pi - \cos\frac{1}{2}n\pi\right)\frac{2}{n\pi}\cos nx$

5.



$\cos x + \frac{1}{2}\cos 2x + \frac{1}{3}\cos 3x +$

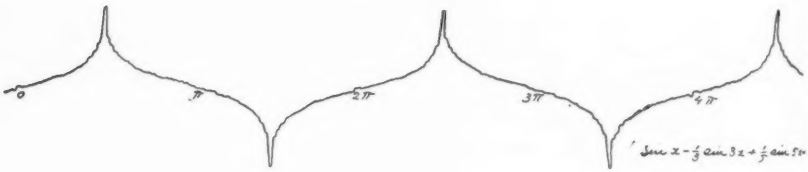
$-\cos x + \frac{1}{3^2}\cos 3x - \frac{1}{5^2}\cos 5x +$

$1 - \cos x + \frac{1}{3^2}\cos 2x +$

$\cos x + \frac{1}{3^2}\cos 3x + \frac{1}{5^2}\cos 5x +$

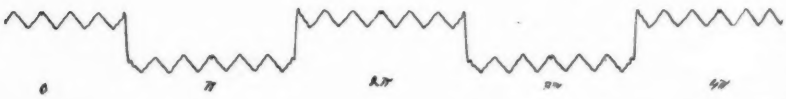
6.

$\cos x - \frac{1}{3}\cos 2x + \frac{1}{5}\cos 3x -$



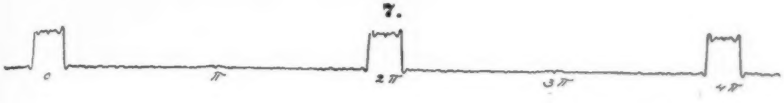
$\sin x - \frac{1}{3}\sin 3x + \frac{1}{5}\sin 5x$

$\cos 4x + \frac{1}{3^2}\cos 12x + \frac{1}{5^2}\cos 20x + -\frac{1}{10^2}\cos$



$\cos x - \frac{1}{3}\cos 3x + \frac{1}{5}\cos 5x + + \frac{1}{4^2}[\cos 12x + \frac{1}{3^2}\cos 36x +]$

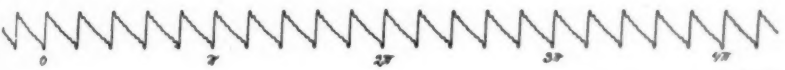
7.



$$\sum \frac{\sin n\pi}{n\pi} \cos nx.$$

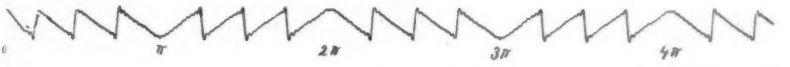
$$-[7\cos 10x + 6\cos 20x + 5\cos 30x + \ldots]$$

$$[8\cos 5x + 7\cos 15x + 6\cos 25x + \ldots]$$

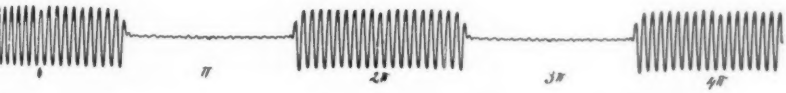


$$\sin 10x + \tfrac{1}{2}\sin 20x + \tfrac{1}{3}\sin 30x + \ldots$$

8.

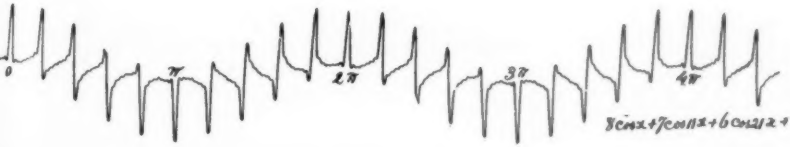


$$a_n = -\frac{1}{n}\left[\sin n\tfrac{\pi}{4} + \sin 2n\tfrac{\pi}{4} + \sin 3n\tfrac{\pi}{4}\right] + \frac{4}{\pi n^2}\left[1 - \cos n\tfrac{\pi}{4}\right]$$



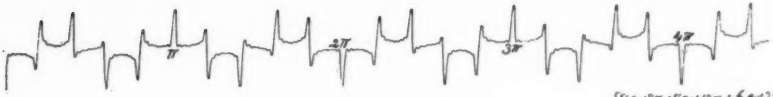
$$15\cos 40x + \left\{\begin{array}{l} \cos 41x - \tfrac{1}{3}\cos 43x + \tfrac{1}{5}\cos 45x - \\ + \cos 39x - \tfrac{1}{3}\cos 37x + \tfrac{1}{5}\cos 35x - \end{array}\right\}$$

$$\cdot \sum \frac{\cos nx}{n^2 - 5} \quad \text{odd terms.}$$



$$8\cos x + 7\cos 11x + 6\cos 21x + \ldots$$

9.



$-[8\cos x + 7\cos 11x + 6\cos 23x + \ldots]$

$-[8\cos 4x + 7\cos 14x + 6\cos 24x + \ldots]$

$\cos x + 7\cos 2x + 4\cos 5x + 2\cos 8x + \cos 11x + \ldots$

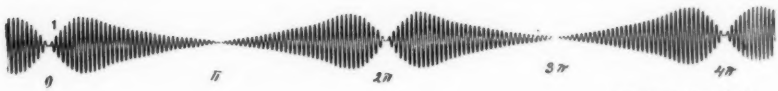
$\cos x + 7\cos 2x + 6\cos 4x + 2\cos 8x + \cos 12x + \ldots$

10.

$\cos 20x + \cos 77x$

$\cos 41x + \cos 80x$

$\cos 40x + \frac{1}{2}\cos 76x$



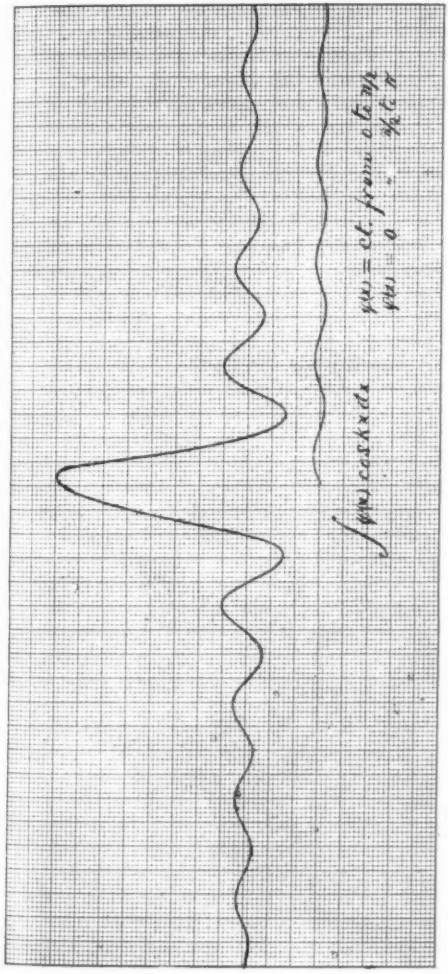
$\cos 74x + \frac{1}{2}\cos 73x + \cos 76x - \frac{1}{2}\cos 77x -$

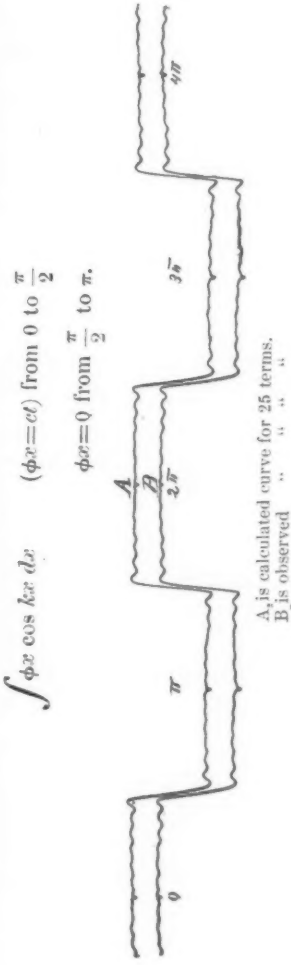
of finding for any given function the coefficients of the corresponding Fourier series.

Thus if $$f(x)=a_0+a_1\cos x+a_2\cos 2x+$$

we have $$a_k=\frac{2}{\pi}\int_0^{\pi} f(x)\cos kx\,dx$$

11.





On the other hand, if n is the number of an element of the machine and a the distance between any two elements, and the

amplitude d (fig. 1) is proportional to $f(n\alpha)$, the machine gives

$$\sum_{0}^{m} f(n\alpha) \cos n\theta = \sum_{0}^{\pi} f(x) \cos \frac{m}{\pi} \theta x$$

which is proportional to a_k if $k = \frac{m}{\pi}\theta$. Hence to obtain the integral, the lower ends of the vertical rods R (Plate I) are moved along the levers B to distances proportional to the ordinates of the curve $y = f(n\alpha)$.

The curve thus obtained for a_k is a *continuous* function of k which approximates to the value of the integral as the number of elements increases. To obtain the values corresponding to the coefficients of the Fourier series, the angle $\theta = \pi$, or the corresponding distance on the curve, is divided into m equal parts. The required coefficients are then proportional to the ordinates erected at these divisions.

Figure 11 gives the approximate value of $\int \varphi(x) \cos kx\, dx$ when $\varphi(x)$ = constant from 0 to a, and is zero for all other values. The exact integral is $\frac{\sin ka}{k}$. The accuracy of the approximation is shown by the following table, which gives the observed and the calculated values of the first twenty coefficients for $a = 4{\cdot}0$.

$$\int_0^a \cos kx\, dx$$

n.	obs.	calc.	△
0	100·0	100·0	0·0
1	65·0	64·0	1·0
2	0·0	0·0	0·0
3	—20·0	—21·0	1·0
4	0·0	0·0	0·0
5	12·5	13·0	—0·5
6	—1·5	0·0	—1·5
7	—9·0	—9·0	0·0
8	0·0	0·0	0·0
9	6·0	7·0	—1·0
10	0·0	0·0	—2·0
11	—6·0	—6·0	0·0
12	0·0	0·0	—0.0
13	4·0	5·0	—1·0
14	—2·0	0.0	—2·0
15	—4·0	4·5	0·5
16	0·5	0·0	0·5
17	8·5	4·0	—0·5
18	—1·0	0·0	—1·0
19	—3·5	—3·0	0·5
20	0·0	0·0	0·0

The average error is only 0·65 of one per cent. of the value of the greatest term.

The accuracy of the result is also shown in curves A and B (fig. 11). The former gives the summation of the calculated terms and the latter of the observed.

Another illustration is given in figure 12 in which

$$\varphi(x) = e^{-a^2 x^2}$$

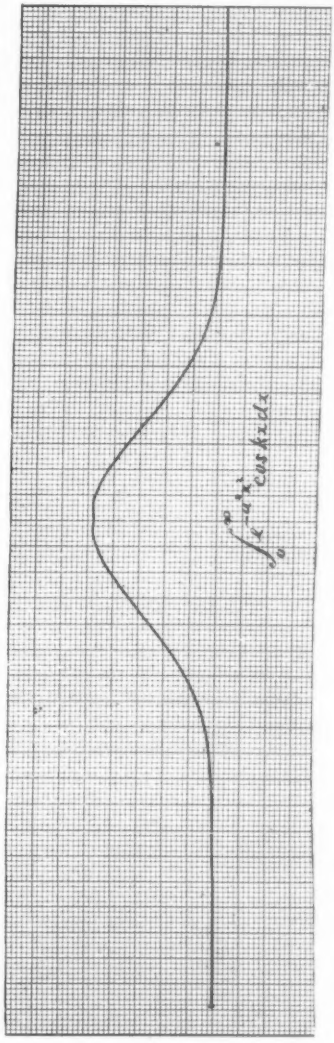
For $a = \cdot 1$ the following are the values of the coefficients of the first twelve terms of the equivalent Fourier series.

$$\int_0^\infty e^{-a^2 x^2} \cos kx \, dx$$

n.	obs.	calc.	△
0	100·0	100·0	0·0
1	95·0	96·0	—1·0
2	85·0	86·0	—1·0
3	70·0	70·0	0·0
4	53·0	54·0	—1.0
5	38·0	38·0	0·0
6	25·0	25·0	0·0
7	16·0	15·0	1·0
8	8·8	8·0	—0·8
9	5·0	4·5	0·5
10	3·6	2·0	1·6
11	2·4	1·0	1·4
12	1·6	0·5	1·1

Here the average error is only 0·7 per cent of the value of the greatest term.

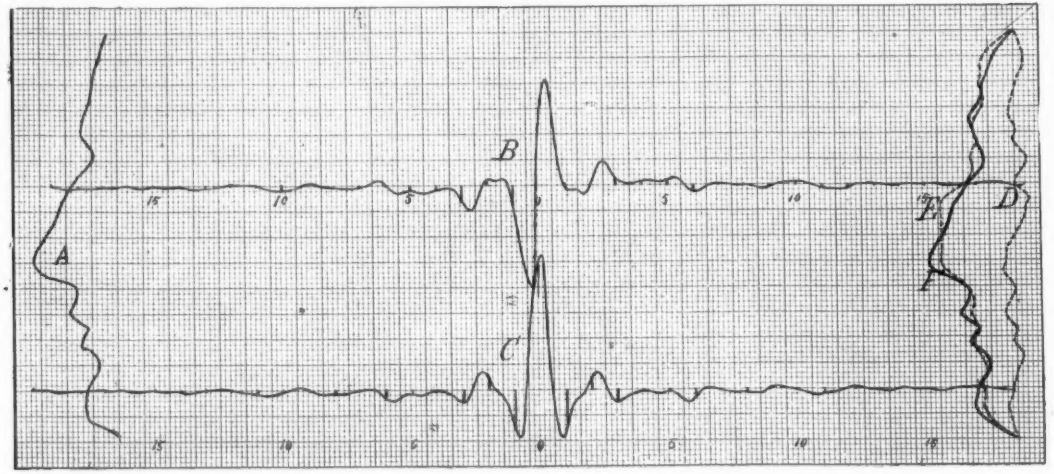
12.



The complete cycle of operations of finding the coefficients of the complete Fourier series (sines and cosines) and their recombination, reproducing the original function, is illustrated in figure 13. A is the original curve. B and C are the values of $\int \varphi(x) \sin kx \, dx$ and $\int \varphi(x) \cos kx \, dx$ respectively. Their in-

$$F=\phi(x)= \begin{array}{llll} & 15\sin\theta & -75\cos\theta & -2\sin 11\theta-10\cos 11\theta \\ -10\sin 2\theta & +21\cos 2\theta & -5\sin 12\theta+ & 1\cos 12\theta \\ +20\sin 3\theta & -24\cos 3\theta & +4\sin 13\theta+ & 0\cos 13\theta \\ +\ 8\sin 4\theta & -\ 3\cos 4\theta & +0\sin 14\theta+ & 0\cos 14\theta \\ +10\sin 5\theta & -\ 8\cos 5\theta & +1\sin 15\theta+ & 0\cos 15\theta \end{array}$$

$$F=\phi(x)= \begin{array}{llll} - & 8\sin 6\theta & -18\cos 6\theta & -2\sin 16\theta-\ 1\cos 16\theta \\ + & 4\sin 7\theta & -\ 1\cos 7\theta & +1\sin 17\theta+\ 0\cos 17\theta \\ + & 2\sin 8\theta & -\ 8\cos 8\theta & +3\sin 18\theta+\ 3\cos 18\theta \\ - & 5\sin 9\theta & +\ 1\cos 9\theta & -2\sin 19\theta+\ 0\cos 19\theta \\ + & 6\sin 10\theta & -2\cos 10\theta & +0\sin 20\theta+\ 0\cos 20\theta \end{array}$$



$$A=\phi(x) \qquad B=\int \phi(x)\sin kx\,dx \qquad C=\int \phi(x)\cos kx\,dx$$

$$D=\sum_{0}^{20} B\sin n\theta \qquad E=\sum_{0}^{20} C\cos n\theta \qquad F=D+E$$

tersections with the ordinates midway between the heavier ordinates, give the coefficients of the sine and cosine series respectively. The sums of the first twenty terms are represented by the curves D and E, and finally the sum of these two curves produces the curve F, which agrees sufficiently well with the original to be easily recognizable.

It appears, therefore, that the machine is capable of effecting the integration $\int \varphi(x) \cos kx\, dx$ with an accuracy comparable with that of other integrating machines; and while it is scarcely hoped that it will be used for this purpose where great accuracy is required, it certainly saves an enormous amount of labor in cases where an error of one or two per cent is unimportant.

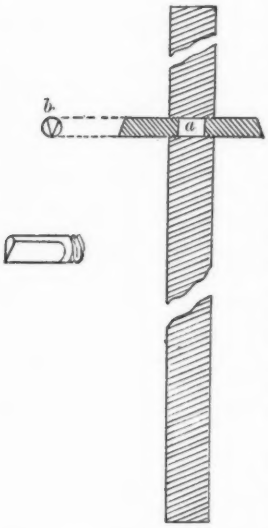
The experience gained in the construction of the present machine shows that it would be quite feasible to increase the number of elements to several hundred or even to a thousand with a proportional increase in the accuracy of the integrations.

Finally it is well to note that the principle of summation here employed is so general that it may be used for series of any function by giving to the points (p) the motions corresponding to the required functions, instead of the simple harmonic motion furnished by the excentrics. A simple method of effecting this change would be to cut metal templates of the required forms, mounting them on a common axis. In fact the harmonic motion of the original machine was thus produced.

Ryerson Physical Laboratory, University of Chicago.

ART. II. — *A New Form of Physical Pendulum;* by JAMES S. STEVENS.

IN the determination of g by the common form of physical pendulum an error is introduced on account of the fact that the knife-edges and clamp affect the moment of inertia and the center of gravity of the pendulum, and in consequence the period. A form of pendulum in which these errors are eliminated has been found satisfactory in my laboratory work. A hole was bored through a brass cylindrical rod, about 8 cms. from one end. The knife-edges for the support of the pendulum were screwed a little way into the hole, and their mass adjusted so that they offset the mass of the brass bored out. This is represented at a in the sketch. In this manner the center of gravity of the system remains at the position of the center of gravity of the original bar.



The source of error would be entirely removed if the center of oscillation of the triangular knife-edges were in the same horizontal plane as that of the removed cylinder. If we call the radius of the cylinder r, the distance of the center of oscillation to the point of suspension is in the case of the triangle $\frac{5}{4}\ r$, and in the case of the cylinder $\frac{3}{2}\ r$. Allowing for the relative densities of the steel and brass, the knife-edges may be so constructed and inserted that this result may be brought about. If, however, this error is neglected, the effect will be a raising of the center of oscillation in the region from which the brass has been removed, of $\frac{1}{4}\ r$.

In the pendulum used r is about one-half a centimeter. The bar is one meter long and therefore the true length of the pendulum may be taken as approximately sixty-two centimeters. Therefore the error in g due to the error under consideration would not exceed 0·03 cm. This is of an order more precise than is usually obtained by any method of finding g in the laboratory.

ART. III.—*The Protostegan Plastron;* by GEORGE R. WIELAND. (With Plate II.)

OWING to the fact that the bones of the plastron of the turtles from the older formations are usually fragile and are made up of many parts, we have but few restorations of this portion of the testudinate skeleton from pre-Tertiary species. And so far as the gigantic turtles of the American Cretaceous are concerned we lack a complete restoration entirely, though Hay has given a partial restoration of *Protostega gigas* Cope.*

The present contribution may in some degree fill up this gap. It is based on two specimens of the turtle closely related to Protostega, which I have described as *Archelon ischyros*,† both of which I collected near the Cheyenne River in South Dakota from the very uppermost Fort Pierre Cretaceous.

As these plastra, though fairly well preserved, were broken into hundreds of pieces while yet in place, it has not been thought advisable to indicate fractures. Nor has it been deemed necessary to indicate in the illustrations that the external spines of the left hyo- and hypo-plastron have been in part determined from those of the corresponding elements of the right side. The fact that all the figures given are from a single specimen, as confirmed by a second, adds to their value.

General Description.

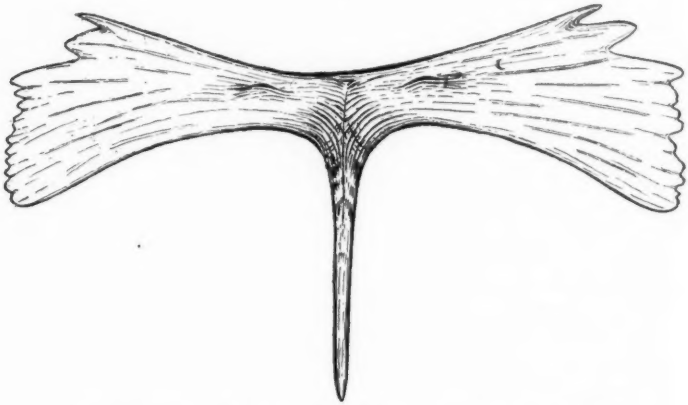
The Entepiplaston (see measurements, p. 19).—The most striking feature of the protostegan plastron is the distinct fusion or lack of separation of the three anterior plastral elements,—that is, of the entroplastron and the two epiplastra. This single element is a feature hitherto unobserved in the Testudinata and may be described as the *entepiplaston* or *paraplastron*. It is a rather heavy and a very shapely bilaterally symmetrical T-shaped bone, gracefully curving outward into two broad alæ which slowly thin out to no more than the thickness of cardboard along their posterior edges. Anteriorly the edge is rounded except in the central portions, where there is a distinct downward and outward-looking external chamfer. At each forward extremity of the alæ there is one distinct spine followed by a second which is flat and thin. The remainder of the outer edge tends toward termination in thin spines. While the outer surface is somewhat convex in general relief, the inner is slightly concave and flat except for two lateral longitudinal bosses about six centimeters long, one centimeter high and twenty centimeters apart, anterior to which are

* Field Columbian Museum Publication 7, Chicago.

† See this Journal for December, 1896.

small furrows. The long medial posterior or entoplastral process is, however, distinctly triangular for the first third of its length, and for the remainder quite round. The entire surface of this bone is striated like the remainder of the plastron, and not like the carapace.

1.



Entepiplastron. Upper or internal side. One-tenth natural size.

That we have in this bone a true plastral element was decided from the following reasons and facts:

1. Its size and particularly its form will permit the supposition that it represents the entoplastron and epiplastra.

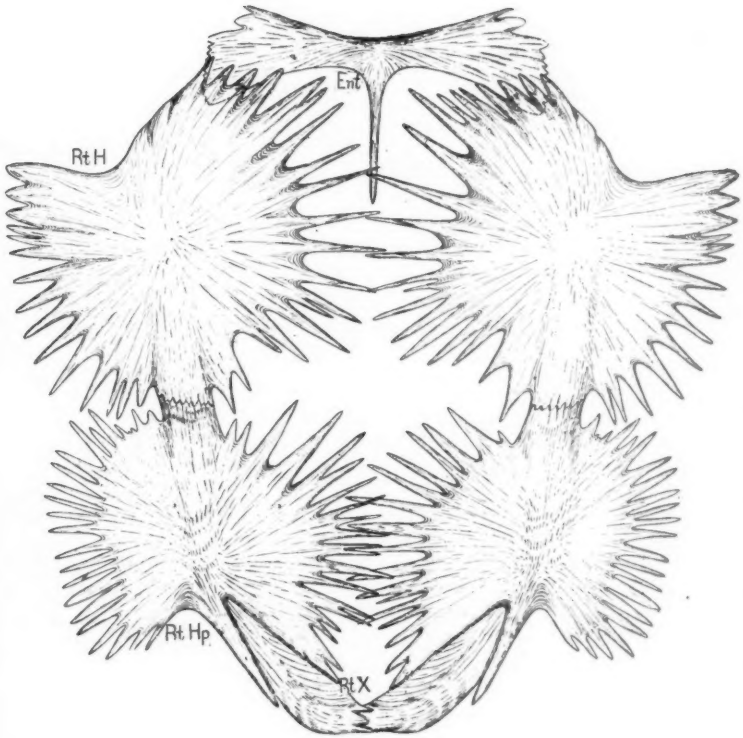
2. There is the possibility that the epiplastra or their homologue could lie athwart the anterior extension of the hyoplastræ, as is distinctly the tendency in *Sphargis*.

3. I have twice seen this bone in place, and each time it rested directly upon the anterior portions of the hyoplastra and beneath numerous other skeletal parts, while the angular edge of the entoplastral process faced upwards, and therefore inwards as would be expected. Rounded edges and flat faces would probably be exterior.

4. The chances were in favor of the preservation of other plastral elements, rather than of such a free nuchal as this bone would have constituted, had they existed. Especially was this the case in specimen No. II, where the anterior parts were quite undisturbed.

5. There is no process for articulation with the last cervical vertebra as in all living marine testudinates.

6. Were this bone to be regarded as the nuchal, and the remainder of the plastron then to be added to proportionally for



THE PLASTRON OF PROTOSTEGA ISCHYRA (*Wieland*).

The under or external view of a series of elements, all of which were found in contact relatively in the above position and beneath all other skeletal parts present.

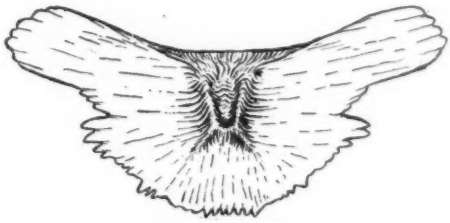
One-twentieth natural size.

Rt. H = Right Hyoplastron.
Rt. Hp. = " Hypoplastron.
Rt. X. = " Xiphiplastron.
Ent. = The Entepiplastron (?).

anterior plastral elements as in Tholassochelys, etc., the plastron would probably have had a greater length than the carapace.

7. There is an element which I figure and think must be the nuchal. It resembles markedly the nuchal of Sphargis and corresponds closely to the bone which Cope believed to be the nuchal of *Protostega gigas*, (Cretaceous Vertebrata of the West, plate XII, fig. 11.) The figure and description is given herewith. The *nuchal* (see meas.) is a flat fan-shaped bone distinctly incurved anteriorly, and spreading out into two broad alæ projecting well forward. These must have con-

2.



Nuchal. Under or internal side. One-tenth natural size.

nected with the marginalia, the anterior pair of which were quite thin, fragments having been recovered. It should be remarked that the thickness laterally and also of the thin posterior fan, the edge of which is slightly notched as if for sutural union with the first neural, as well as striation, all favor the nuchal position for this bone. The latter is especially true of a small dorsal pitting from which radiate several distinct surface striations corresponding to those radiating from the median neural groove* of the carapace. The inferior side is marked by a prominent centrally-placed elevation two centimeters in height, having the shape of an isosceles trapezoid distinctly buttressed at the four corners. The long and anterior base of this trapezoidal ridge has twice the length of the shorter, and a slight central elevation is enclosed. This elevation must have formed a surface for articulation with the last cervical vertebra. This element evidently formed no part of the plastron, and as I have previously described the pygal I can suggest no other than the nuchal position. (See Figure 2.)

Hay, in his publication previously mentioned, figures a portion of the entepiplastron which he says must be regarded as the nuchal. He mentions the grooves of the [upper] surface as internal, that is, facing downward, and presumably representing contact with transverse processes of the last cervical

* See description of carapace, this Journal, Dec. 1896, page 400.

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vertebra. But, whether or not it shall transpire that my contention is correct, it must be borne in mind that these markings *faced upwards.* If this element had been the nuchal, whence came they? They were never in contact with any vertebral processes unless such projected downwards.

The Hyoplastron (see measurement).—This element of the plastron is traversed by and marks the end of a continuous heavy ridge beginning with the heavy outer edge of the comparatively narrow xiphiplastron and continuing through the hypoplastron. Considered in its general outline, this ridge strongly suggests the beginning of a reduction resulting in a plastron like that of *Sphargis.*

From its central ridge the hyoplastron, which is broadly elliptical in general outline with the exception of the large brachial notch, grows steadily thinner on both sides until it consists simply of flat ridges marking the emergence of the spines which beset it on every side except the brachial, the edges being no thicker than cardboard.

These spines narrow and thicken toward their middle portions. Those of the inner edge may be roughly divided into an anterior, a medial and a posterior group. The spines of the anterior group, seven to nine in number, are very heavy and rather short and incline to or are distinctly triangular in section with the flat surface beneath. Those of the medial group, six in number, are very long and slender. For their last third they are crescentic in cross section, the concave faces facing in pairs. The last or inferior group consists of rather flat spines. There are nineteen spines in all on the right interior and twenty-one on the left. Where two take the place of one the general symmetry is preserved by a diminution in size.

On the outer edge following the brachial angle there are three broad, heavy and rather short spines, followed by three longer and more slender; the remainder of the outer hyoplastral series being rather broad and flat.

There is absolutely no marginal or surface marking whatever suggesting contact with an *epiplastron.* (See Plate II.)

The Hypoplastron (see measurements).—This bone strongly resembles the hyoplastron in general appearance, though the spines are more numerous and less divided into regions, with the exception of the two long posterior extensions which receive the xiphiplastron between them. The right and left inner series overlap considerably. Inner series of spines, right side, 20; left, 17; outer series, 17 in number.

The Xiphiplastron (see measurements).—Except for the slightly dactylated connection between the posterior ends of the xiphiplastrals there are no spiny processes. The outer edge

thickens into a rounded and heavy ridge previously mentioned, while the inner edge thins out as it passes beneath the posterior extension of the hypoplastron. Anteriorly there are two lateral grooves for the reception of the two posterior hypoplastral continuations. This dovetailing makes a very firm joint between these two elements.

Concluding Remarks.—From the further study involved in the reconstruction given herewith I conclude that the genus Archelon which I have proposed is unnecessary. *Archelon ischyros* therefore becomes *Protostega ischyra*. Certain differences I pointed out in the processes of the humerus and procoracoscapular together with unusually robust form and increase of size are of distinct specific but not generic value. I may mention that Cope represented the ribs of Protostega as free and that Hay with additional material considered this possible. The rib expansions unquestionably united in *gigas* by suture as in *ischyra*, as Professor Cope has since assured me must have been the case.

Cope regarded Protostega as the type of a new family which he did not name, but with the idea that the plastral elements were dorsal—an error much more easily made than one might at first think—especially since some of the marginalia do actually develop into thin dorsal spine set extensions.

Of the generic and family relations of these important forms I shall have more to say at a subsequent time.

Measurements.

The Entepiplastron.

	M.
Extreme length (lateral)	·94
Antero-posterior length	·45 ±
Greatest breadth of alæ	·28
Least breadth of alæ	·10
Least circumference of alæ	·21
Thickness at least circumference	·05
Greatest thickness in medial line	·06
Length of entoplastral process	·36 ±

The Hyoplaston.

Greatest antero-posterior length inclusive of spines	1·03 ±
Greatest oblique length inclusive of spines	1·20 ±
Greatest width inclusive of spines	1·10 ±
Greatest antero posterior length exclusive of spines	·92
Greatest width exclusive of spines	·70
Greatest thickness	·048
Length of interior spines	·15—·25
Length of exterior spines	·15—·20

The Hypoplastron.

Greatest length inclusive of spines	1·00
Greatest width inclusive of spines	1·00±
Greatest length exclusive of the posterior extension	·65
Greatest width exclusive of spines	·65
Greatest thickness	·041
Length of interior spines	·15—·25
Length of exterior spines	·10—·20

The Xiphiplastron.

Greatest length	·50
Greatest width	·17
Greatest thickness	·036
Thickness near terminus	·025

The Plastron.

Total width across the hyoplastron	2·00+
Total width across the hypoplastron	1·86
Total length	2·00+

The Nuchal.

Greatest lateral width	·64
Antero-posterior length	·25
Elevation of articulating surface for the last cervical vertebra	·02
Greatest thickness including the process for the cervical	·035
Width of alæ	·09
Thickness of alæ	·01—·015

Chester, Pa., Dec. 11, 1897.

Art. IV.—*The Granitic Breccias of the Cripple Creek Region;* by George H. Stone.

In his report on the geology of Cripple Creek* Mr. Whitman Cross has devoted considerable space to the fragmental volcanic rocks of the district. In the present paper I wish to record some additional facts as to the dike phenomena of the region in question, the result of observations made in the years 1894–97. The following named dikes include only the more typical localities. They have been purposely selected from outside the central volcanic district, where they are in the midst of granites and the older crystalline rocks. In such situations the dikes are isolated and it is easy to distinguish their deposits from other volcanic matter.

Tuffs and breccias composed chiefly of volcanic rock, sometimes with an admixture of older rocks, have long been known. They are well represented in the Cripple Creek district, and having been well described by the authors above cited, need not here be further mentioned. The fragmental rocks now to be described are remarkable for consisting of non-volcanic rocks. They are of a kind not before recognized, within my knowledge, as of volcanic origin. Their general characteristics are the following.

They are invariably found capping and bordering the outcrop of volcanic dikes, and in no other situations. My conclusion is that this relationship is causal. They consist of fragments of granites, schists, and others of the older rocks that are penetrated by the dikes. The fragments composing them vary in size from rock flour up to four feet or more in diameter, and all are more or less smoothed and rounded, often as much so as the stones on the ocean shore. When the granitic fragments are uncemented they are found at the sides of the dikes, where they overlie uneven surfaces of the granites and schists, proving that the country was already much dissected by erosion at the time of their deposition, and the same is true of all the granitic breccias; and in this case, if there is a breccia of volcanic rock accompanying the granitic gravel, it overlies the latter. When the granitic stones are cemented into a firm grit the positions are reversed; the upper portion of the grit consists wholly or almost wholly of granitic fragments, but as we go down in shafts we find an increasing amount of the volcanic rock mixed with the granitic, until we reach a dike or

* Geology and Mining Industries of the Cripple Creek District, Colorado. By Whitman Cross and R. A. F. Penrose, Jr. Extract from the Sixteenth Annual Report of the U. S. Geological Survey, 1895. See pp. 50, 60–64, 78, 81, 86, 88, 90, 92, 94, 95, 100.

a breccia composed of the fractured upper portion of a dike, and below this the dike. Sometimes in the granitic breccias we find kinds of rock which are known to be common as inclusions in the granite of the region (e. g. the Algonkian quartzite), but which do not on the surface appear in the granite near the dike. Some of the dikes in question reveal the dynamics of the process whereby the granitic grits were made. The same materials which in some cases we find as beds covering the steep slopes of the hills, in other cases are found beneath the surface between walls of granite but always capping volcanic dikes. My inference is that all have the same origin and consist of volcanic ejectamenta that were pushed up slowly and quietly by the dikes.

Some, perhaps most of the facts here recorded, have been revealed by mining operations since the exploration of the district by Messrs. Cross, Penrose, and Mathews.

At first glance one might suppose the granitic breccias are merely a matter of detail. In the sequel they are found to involve questions of stratigraphy, and therefore it becomes necessary to set forth the facts somewhat fully.

1. The case of a dike that did not reach the surface and did not move after solidification. Elevation 9300 feet.

Such a dike is revealed in the Arcadia workings on the Lone Star No. 1 claim, situated in Poverty Gulch, city of Cripple Creek. The 125 feet level shows a dike, much decomposed but probably phonolite, which is about three feet wide at the bottom of the drift. The dike rapidly tapers upward so as to end six feet higher in a rather sharp edge, though it sends out some stringers ten feet or more into the schists above, somewhat in saw-tooth fashion. The dike-rock solidified fast to the walls and still closely adheres to them, hence has never moved relative to the walls since solidification. Above the dike the schistose rock is broken by joints running in every direction, but none of these crevices appear to be predominant or the upward prolongation of the fissure occupied by the dike. The appearance is not as if the earth's crust was bodily broken by a fracture that started from a great depth and extended all the way to the surface instantaneously. The appearance is as if the fracture had been opened progressively by the lava itself as the agent. The lava ended above in a liquid wedge which sent out tongues into every crevice. Then as the liquid rose, according to the law of hydrostatic pressure, it pressed laterally so as progressively to wedge apart the walls, and open the way for the rising lava. Nowhere in the Cripple Creek region has any one discovered proof that the granites, schists, or even the older volcanic rocks, at any depths yet observed, were melted by contact with the liquid lava, though they are usually honey-

combed and more or less decomposed. We therefore cannot admit that the dike fissures were either opened or enlarged by the melting of the older rock and its absorption into the liquid lava.

2. The case of a dike whose upper extremity moved after solidification. Elevation 10,120 feet.

About a mile west of Gillett is a phonolite dike, a mile or more in length. It everywhere pitches to the west, but on the Ed. Wolcott claim, a few hundred feet northeast of the Lincoln mine, it dips less than the average, about 20° below the horizontal. In one of the shafts at a depth of about 30 feet, this dike is seen to be three feet thick and to be frozen fast to the adjacent granite, proving that at this depth there has been no motion of the dike since solidification. The dike is here crossed by cracks in various directions, but the sides of the blocks of fracture are not slickened. Near 50 feet eastward is another shaft which cuts through nine feet or so of somewhat shattered granite, there penetrates a bed of gravel consisting of broken phonolite, and then enters the granite again. The gravel bed dips toward the dike in the more western shaft and evidently is the same dike, but in a broken condition. Most of the pieces of phonolite are subangular in outline, and all are more or less smoothed and rounded at the angles of fracture, but some are quite round and pebble-like.

The interpretation is unmistakable. The front end of the dike solidified while the lower portion still remained liquid. Probably this happened during a pause in the advance of the dike. Whenever the dike moved after solidification, the solid lava would be broken up and the pieces were slickened by their grinding against each other and the uneven granite walls of the dike. The workings do not show the length of the portion of the dike that was pushed forward after solidification. It could not have been more than about 50 feet, that is, the part now beneath the surface of the granite. All this happened beneath the surface of the granite, where there can be no suspicion of ice action or of either surface or subterranean waters to smooth the stones in question. Indeed it is not certain that the dike here reached the surface, though it did for most of its course for a mile or more, and the outcrop is marked by low ridges of phonolite blocks having their original shapes of fracture somewhat modified by their being polished and a little rounded at the angles. On the hill south of the Lincoln mine these smoothed blocks form a crooked double ridge enclosing a hollow between the two ridges. There is thus the most ample proof that the frontal portion of the dike continued its upward motion after solidification. I have not examined the broken portion of the dike with the compound microscope, but under

the simple magnifier it appears devoid of glass and substantially like the ordinary scoriaceous and somewhat cellular phonolite found at the top of many of the dikes in this district. The smoothed blocks that form the outcrop of this dike form low ridges from 200 to 500 feet wide. If there had been a large amount of erosion since their deposition, they would not as now form compact heaps but would have become widely scattered down the hillsides.

3. The Alhambra. Elevation 9730 feet.

This mining claim is situated low down on the southwestern spur of Squaw Mountain.

A granite ridge is here strewn with bowlders of a firm sand rock, composed almost wholly of crushed granite. Much of it is somewhat porous by the removal of the feldspar and mica grains by vein waters. In some places the rock is practically quartzite by the replacement of the mica and feldspar with silica. It contains a small proportion of crushed phonolite. The more siliceous and iron rusty parts run high in gold, and some 150 tons of bowlders of this class have been picked up on the surface and were shipped as good pay ore.

Several shafts, pits, and trenches, now mostly inaccessible, show that a phonolite dike here rises through the granite, but none of the solid dike reaches the surface. Specimens supposed to come from a depth of 80 feet show that at that depth the phonolite is frozen fast to the granite. Nearer the surface is a body of uncemented phonolite gravel, proving that this portion of the dike was pushed forward and broken up after solidification. Nearer still to the surface is a body of mixed granitic and phonolite gravel, somewhat cemented. At the surface and scattered over the adjacent granite are the bowlders of sand rock already described. These bowlders have smoothed surfaces, proving that after the sand had become cemented into a solid rock, the rock was fractured by the upward movement of the dike and the blocks then received a secondary grinding. They were piled in a ridge along the line of the dike and in the course of time have become scattered over an area about 300 feet wide. This is proof of a limited erosion since the dike period. This fact together with the finding of gold in the sandstone unite to prove the eruption comparatively recent.

Squaw Mountain rises steeply several hundred feet above the Alhambra, which is thus proved to lie far below any ancient floor of the sea. The sand-rock cannot be a remnant of a marine bed. If it be the remains of a lake bed, where is the rest of the bed? There is no other rock like this within half a mile of the Alhambra, though there are several similar deposits of sand-rock in the town of Victor and vicinity, but

always along the line of dikes. After I learned the secret of the Alhambra rock I was repeatedly able to trace the courses of invisible dikes by "float" consisting of pieces of granitic sand-rock mixed with the other surface wash and debris.

4. Rhyolite dike situated about two and one-half miles southwest of Cripple Creek, on the top of the ridge lying between Pony and Long Hungry gulches. Elevation about 8800 feet.

The country rock is a massive granite containing a few inclusions of black mica schist. No part of a massive dike appears on the surface, but that this is the outcrop of a rhyolite dike is proved by the following facts.

The inevitable prospector has located a mining claim on the formation and dug a hole ten feet deep, now half filled with water. This shows that between walls of granite there is a body of fragmental matter. Most of it consists of granite, but there is also a small admixture of rhyolite. Much of the rhyolite consists of small well worn grains and powder, but here and there are subangular fragments up to two and even three feet in diameter. The rhyolite is somewhat porous. The form of the larger rhyolite fragments is quite irregular, a little inclined to be ovate, but with an uneven surface covered with projecting points and edges barely smoothed at the angles. Many of these rough fragments are scattered over the hillside near: these will be referred to hereafter.

The portion of the breccia consisting of the older rocks consists mostly of granite like that composing the walls of the dike. Some of the larger pieces of granite form cobbles 4 to 6 inches in diameter, as round and smooth as any stones on the ocean shore or in the eskers of New England. Much of the breccia consists of a sandstone cemented in its present position into a firm grit. One very smooth pebble four inches in diameter was composed of a fine granitic sand-rock. The most surprising thing is the presence in the mass of numerous pebbles and cobbles of Algonkian quartzite showing the characteristic oölitic appearance of the original sand grains. The rock in the region is largely bare of debris and this makes it easy to find inclusions of the quartzite in the granite if such there were, and none were found. The dike evidently penetrated such an inclusion somewhere in its progress upward. Several of these quartzite cobbles show where, after they had been worn to very round and smooth forms, they had been broken and the new surfaces of fracture had barely begun to be smoothed.

The distance between the granite walls is only about four feet. Five feet below the surface (down to the water) I found granitic grits indistinguishable from the other grits here described. The dump shows nothing but the same fragmental materials, therefore this breccia reaches down at least ten feet. We cannot admit sedimentary action under such conditions.

5. Rhyolite dike situated half a mile southwest of Phonolite Peak, about two miles north and west from Gillett. Elevation about 10,000 feet.

At the outcrop of the dike a shaft has been sunk 15 feet into partially consolidated gravel and cobbles with bowlderets up to 18 inches in diameter, many of the latter being much worn and rounded. Part are of rhyolite, most are of granite, like the country rock. The dike outcrops in a rolling region lying west of the extremities of the ancient glaciers that radiated from Pike's Peak. The surrounding country is covered with disintegrated granite. Neither glaciers nor running streams can account for a local deposit of such round stones, and we cannot postulate a lake a few rods in diameter that could have deposited them.

6. Andesite dike at the reservoir of the Water works, situated on a low spur of Mineral Hill, in the northern part of the city of Cripple Creek. Elevation about 9400 feet.

The excavation of the reservoir exposed a mass of gravel and rounded bowlderets and bowlders up to three feet in diameter. A few are composed of andesite and schists, most are of granite. The gravel is cemented into a hard grit. The existing excavations do not reveal the full size and shape of the deposit. Apparently it is a body of granitic gravel which forms a cap to the dike and spreads out laterally over the adjacent granite to a breadth of 300 feet or more. If the gravel is composed of dike ejectamenta we must suppose that the stones were pushed above the surface as loose or incoherent gravel. By sliding and lateral rain wash this came to overlie the adjacent granite and then was cemented into a firm rock in its present position. This is proved by the fact that there are no smoothed bowlders of the cemented grit as at dikes Nos. 3 and 4. The spaces between the larger stones are filled with crushed granite so compact and firmly cemented that it sometimes requires close examination to determine its fragmental character. The size of the deposit is about 300×600 (or 800) feet.

Mr. Cross (l. c., p. 101) suggests that this gravel was deposited in a local lake. For the following reasons I regard it as a breccia or conglomerate composed of ejectamenta pushed upward by the rising dike.

The stones and bowlders vary much in shape. Some are as round as any beach cobbles, most are only moderately rounded at the angles of fracture, and some preserve almost the original shapes of fracture, being only a little polished and blunted at the angles. Many cobbles are rounder than the stones of small lakes become unless transported by long streams, and we cannot postulate such streams in a small mountain cirque bordered

by moderate slopes. On the shores of the largest lakes in Maine the stones of the unmodified till have not since glacial time become so round as many of these cobbles and bowlderets at the reservoir. One per cent or so of the pebbles and cobbles show very round outlines, except on certain sides where they have nearly flat surfaces of fracture but little modified. This proves that many of the stones, after having become round as eggs, were broken and the process of grinding was then renewed, but had not gone far when the movement ceased. Several of the rounder stones had been fractured at each end, and in one case the two planes of fracture were inclined to each other 30°. These fractured cobbles were of massive granite, not of fissile schists. All this is just what a dike could be expected to do if it pushed before it a mass of fragments of the rock it was penetrating, they being confined between solid walls. It would grind and roll and round them and from time to time break them, and we would find every stage from fresh fracture forms to the roundest all indiscriminately mixed as we do here.

The difficulties of the lacustral theory are great and, as I believe, insuperable. In dozens of places in the Cripple Creek region the same sort of granitic grits occur underlain invariably by volcanic dikes, and often underlain by breccias composed largely of volcanic rock. We cannot trace any sharp line of demarcation between these volcanic breccias and the overlying granitic grits and bowlder beds. They pass into each other by degrees; the shapes of the fragments are the same. We cannot postulate so many local lakes, and if we did they cannot adequately account for the shapes of the fragments or the invariable association with dikes. They occur on the tops of hills as well as in valleys, and at such different elevations they cannot be remains of a once continuous formation. A lake having a surf violent enough to roll and round bowlders up to four feet in diameter ought to be able to excavate a beach cliff and terrace and to plane off the rock to water level. Nothing of the kind has been found anywhere in the Cripple Creek region. On the contrary, these granitic grits overlie steep slopes of erosion. On this point my observations accord with Cross's descriptions. But in the case of dikes numbered 3, 4, and 5, the same sort of rounded stones and bowlders occur between granite walls and beneath the surface, where there can have been no sedimentation by lakes or streams. The lacustral theory is thus proved to be needless. We can account for everything on the volcanic theory.

7. Rhyolite dike situated about one mile southeast of Marigold. Elevation 8000 feet.

This dike is situated on the top of the high ridge that lies

between Cripple Creek and Spring Creek, a small stream that flows southwestward from the south end of Grouse Mountain. It is about half a mile east of Four Mile Creek.

The country rock is granite. The dike both laterally and on the top is covered with a deep body or layer of breccia or conglomerate; a bowlder bed would be a better term for it. The fragmental materials consist chiefly of granitic pebbles, cobbles, bowlderets and bowlders up to four feet in diameter. Most of them are as round as any bowlders to be found anywhere. The spaces between the larger stones are filled with crushed rhyolite and granite mixed. The bowlder bed forming the top of the dike rises quite steeply 100 feet above the surrounding granite. It is now cemented into quite a firm rock, yet large blocks have fallen away from the precipitous cliffs and are now found far down the southern slopes toward Spring Creek. One mass 80 feet in diameter may or may not have come from above in this way. On some of the steeper cliffs, where the outer layer above described has broken away, we find a semi-breccia composed of well-rounded granite stones and bowlders embedded in the rhyolitic lava itself. None of the massive rhyolite is exposed.

The surface portions consist wholly of fragmental materials. Structurally they are as well entitled to be termed lake beds as the bowlder bed at the Cripple Creek reservoir, or any other of the bodies of rounded granitic stones in this district. At the reservoir the granitic gravel was pushed up in a loose condition and was not cemented till after it had reached the surface and had time to spread over the granite at the sides of the dike. But at this dike near Marigold the granitic stones were cemented fast to the top of the dike before it rose above the granite, a very convenient thing for the investigator. The dike and the material it pushed before it as it rose are there now in position to testify to what sort of work the dikes did as they were pushed upward. This dike is about 600×200 feet in area.

8. Phonolite dike on Straub Mountain. Elevation of the grits 9300 feet and from thence rising along rather steep slopes up to 9800 feet.

This very large dike is bordered and in part overlain by a broad mass of grit consisting of subangular granitic sand and gravel and now and then a few fragments of phonolite. Some of the stones are quite smooth and pebble-like. These grits are mapped by Mr. Cross as High Park Lake beds. They, as well as dikes here numbered 9 and 13, have been well described by Cross, and hence need only brief reference here. They overlie uneven slopes of pre-volcanic erosion. Neither in materials nor in shapes of the fragments do they differ from

the grits found at dike No. 4 between granite walls. I consider them as granitic breccias composed of dike ejectamenta.

9. Phonolite and rhyolite dikes on Grouse Mt. Elevation of grits from 9100 up to 9800 feet.

This mountain contains very large dikes of both rhyolite and phonolite and both kinds of dikes are capped and bordered by granitic grits. When the grits cap a phonolite dike they contain some fragments of phonolite; when they cap a rhyolite dike they contain fragments of rhyolite. This is strongly against the sedimentary theory of the origin of these grits, which I regard as granitic breccias like the rest.

10. Phonolite dike on Beacon Hill.

At various points along the western slopes of this hill are found granitic grits indistinguishable from the grits on Grouse and Straub Mountains. If the latter are lake beds, so are these on Beacon Hill. Elevation of the grits about 9500 feet.

11. Andesite dike on the top of Mineral Hill. Elevation 10,150 feet.

The extreme top of this hill consists of a firm grit composed almost wholly of granite but with an admixture of andesite. The fragments are rather more angular than at the other dikes here described. Going down in shafts, we find an increasing proportion of andesite. So also as we go down the surface slopes of the hill we find more and more andesite till we soon reach the characteristic andesitic breccia.

The granitic grit on the top of Mineral Hill is plainly a breccia like the more andesitic breccia that underlies it, and they pass into each other by insensible gradations. We cannot account for the granitic fragments as explosive ejectamenta in such a position, but they can easily be accounted for as dike ejectamenta if we suppose they were cemented immediately after being raised above the original surface. This would preserve the continuity of the granitic gravel as a cap and the andesitic fragments pushed up subsequently as a body of loose gravel would spread laterally underneath the cap and gradually be cemented to it.

12. Andesite dike on the N. W. Spur of Rhyolite Mountain. Elevation 9900 feet.

Here some mining shafts penetrate an andesitic breccia that is so weakly cemented as soon to fall to pieces after being exposed to the weather. They next pass through a stratum of well-rounded granitic gravel, pebbles and cobbles, and then into the granite. These stones have the same shapes as those at the Cripple Creek reservoir. The most probable interpretation is as follows:

The andesite dike was slowly rising through the granite and as it did so it pushed a mass of granite before it, crushing it in

the process, and smoothing the stones. These fragments were not cemented. As the incoherent gravel and cobbles rose above the surface they formed a ridge, which at the base overlay the adjacent granite, probably in this case to a breadth of less than one-eighth of a mile. But the dike continued to rise. As fast as the upper surface of the lava solidified, it was broken and the fragments were pushed upward in substantially the same way as the granitic fragments had been. The andesitic fragments rose through the granitic fragments, pushing them to one side and ultimately forming a ridge which at the sides overlay the granitic gravel and cobbles. Later the andesitic matter was cemented into a breccia. In places there is no cement to speak of.

Similar granitic grits are found at Little Pisgah and other places that might be named, but these will suffice for the present.

It will be noted that granitic breccias have been found above dikes of rhyolite, phonolite, and andesite only. Outcrops of basalt are well exposed on the American Eagles, top of Bull Hill, also on Galena Hill near Grassy and on Signal Hill, a half mile south of Cripple Creek. In none of these cases did I find any granitic breccias, though the conditions were favorable for finding them if they ever existed.

13. Rhyolite dikes at High Park. Elevation about 8,000 feet.

Here are several miles of rhyolite dikes, all capped and bordered by grits that consist mostly of granitic fragments, but with the schists and especially the Algonkian quartzite well represented, also they contain some rhyolite. Cross (l. c.) includes these among his High Park Lake beds. They have the same general character as the grits already described. These remarks are intended to apply only to that portion of the lake beds that covers and borders the dikes. At a distance from the dikes the lake beds differ in materials and in various other respects from the parts above and near the dikes.

Had the grits on Straub and Grouse Mountains and those capping the rhyolite dikes in High Park been examined by the writer without having the other dikes to compare them with, it is not probable that any other interpretation would have occurred to me than that they were of sedimentary origin. I make this personal reference for the express purpose of acquitting my friend Mr. Cross from any carelessness of observation. The disputed questions involved are all matters of interpretation.

We are now prepared to consider more fully the details of the process of making granitic breccias that so closely simulate sedimentary beds.

It is well known that most volcanic regions show that at times the lava flowed as a liquid over the surface, the flows often alternating with layers of explosive ejectamenta, as at Cap Rock a few miles S.W. of Cripple Creek. The internal structure of the Cripple Creek volcanoes is difficult to make out because the surface is so covered with debris. At the margins of a few of the larger lava bodies I have found signs of a limited lateral flow, but in general the volcanic rocks occur as dikes rather than as flows, and their motion was upward.

The dikes numbered 2, 3, and 4 afford conclusive proof that some of the dikes of the Cripple Creek region solidified at the front before reaching the surface, also that they moved after solidification. This gave the first definite clue to the mystery of the granitic breccias.

Dike 1 shows that the melted lava as it was pushed upward ended at the front in a rather blunt liquid wedge which by hydrostatic pressure successively wedged apart the rocks. This probably could only happen near the surface where the rocks were so broken they could thus be moved relative to each other.

We could naturally expect that as the frontal portion of the melted lava cooled and became more viscous, this wedge would become blunter. The time would come when the front of the rising dike solidified or would become so viscous that the pressure forward would become greater than the pressure tending to wedge apart the solid rocks in front. If at this time the pressure on the liquid from below was feeble or if the liquid lava could force another vent, the movement might be arrested at this point. If the upward movement continued, the only way in which the dike could now rise was by pushing before it a mass of the solid rock it was penetrating, crushing it into fragments, and then as the fragments wedged each other apart and ground against each other and the adjacent walls, it gradually rounded and polished them. The friction would be tremendous and would fully account for the large amount of crushed rock. If at this stage of the process the advance should cease for awhile or become very slow, the heated waters from below, where the lava was still liquid, would under the proper conditions cement the crushed granite into a firm sand-rock while still between the granite walls of the dike, and they might charge it with gold. If the motion were then resumed the capping of sand-rock would be broken into blocks, and as they were pushed onward they would become smoothed and rounded, and would finally form a ridge rising above the adjacent granite.

For a time the liquid lava lay not far below the region of crushed granite. In some cases, especially in case of the rhyo-

lite dikes, the liquid now and then spurted in streams or tongues up into or through the mass of crushed granite, as at dike No. 4, and there cooled. The upward movement immediately began to grind and often to crush these injected bodies.

When the upper crust of the lava became sufficiently thick it was broken up and the pieces pushed onward. At first they preserved nearly their original positions relative to each other and they were slickened at the sides and barely blunted at the angles. If this happened near the surface, as at dike No. 2, the smoothed fragments were pushed above the surface before receiving much attrition and there lay in ridges. But if they were pushed far some of them were crushed and then one by one they were rolled until none of them retained their original positions relative to each other. Those stones that happened to be rolled into many positions received the attrition on all sides and became round. At the sides of the moving dike we frequently find bodies of breccia composed of mixed granite and lava, and in some cases this is known to reach a depth of several hundred feet.

The above interpretation leads to many corollaries. It is impossible within the limits of this article to mention more than two. First, erosion has been limited since the close of the volcanic period. In other words, the present outlines of the volcanic ridges and cones of Cripple Creek are substantially the same as they were originally.

Second, a large part of the volcanic action was comparatively slow and non-explosive.

Specimens of all the breccias here described, except from Nos. 1 and 12, have been placed by me in the collections of the University of Colorado at Boulder, also of the University of Denver and of Colorado College at Colorado Springs. Investigators will thus find them easily accessible.

Finally, there is reason to believe that dike ejectamenta of the kind here described are not uncommon.

Colorado Springs, Sept. 17, 1897.

ART. V. — *On the Dispersion and Absorption of Infra-Red Rays in Rock Salt and Sylvine;** by H. RUBENS and A. TROWBRIDGE.

A SHORT time ago it was pointed out that it is possible to isolate a narrow band of approximately homogeneous rays from the great number sent out by a source of heat by means of successive reflections from a number of surfaces of the same substance. This isolation follows from the selective reflection of the surfaces used.† In this manner comparatively monochromatic rays, in some cases possessing a very great mean wave length, can be obtained without the use of prism or grating.

Compared with the usual method, where dispersion is obtained by means of a prism or grating, this method has, for some research work, the disadvantage that the wave length cannot be varied at will; as one is limited to well defined wave lengths determined by the substance of the reflecting surfaces. For this reason it is of some interest to state to what extent the prismatic method is applicable in the further infra-red spectrum; or else, what wave length can be attained in a spectrum thrown by a sylvine or rock-salt prism.

There are several properties of a body upon which its fitness as a substance for prisms depends. Next in importance to its occurrence in large clear pieces and the possibility of preparing and preserving plane surfaces, come its dispersion and absorption. We undertook, therefore, to determine with the greatest possible precision, the dispersion and absorption of these bodies for infra red rays of great wave length.

Measurement of Dispersion.

The dispersion of rock salt and sylvine has been compared with that of fluorite as far as the wave lengths $8{\cdot}86\mu$ and $7{\cdot}06\mu$ respectively, in a previous investigation undertaken by one of us.‡ For fluorite there exist the careful measurements of its dispersion by Paschen,§ which were made with the help of a Rowland grating especially constructed for this purpose. These measurements extend to the wave length $\lambda = 9{\cdot}44\mu$ and were made after Langley's method. Several additional points of the dispersion curve of rock salt and sylvine have lately been observed in the extreme infra-red at $\lambda = 20{\cdot}6\mu$ and $\lambda =$

* Translated by one of the authors from the original in Wiedemann's Annalen.
† H. Rubens and E. F. Nichols, Wied. Ann., lx, p. 418, 1897.
‡ H. Rubens, Wied Ann., liv. p. 476, 1895.
§ F. Paschen, Wied. Ann., liii, p. 301, 1894.

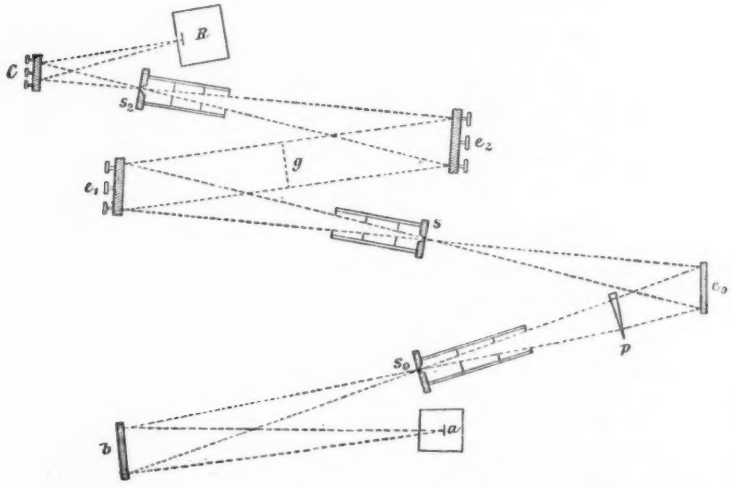
$22{\cdot}3\mu$, and with the help of these points, together with the above mentioned earlier data, the five constants of the Ketteler-Helmholtz equation

$$n^2 = b^2 + \frac{m_1}{\lambda^2 - \lambda_1^2} - \frac{m_2^2}{\lambda_2^2 - \lambda^2},$$

have been calculated.* In the first part of this communication we have limited ourselves to the comparison of the results obtained by means of this formula, with the dispersion of rock salt and sylvine for certain points in the large field between $\lambda = 8{\cdot}86\mu$ and $\lambda = 20{\cdot}6\mu$ for rock salt and $\lambda = 7{\cdot}06\mu$ and $\lambda = 20{\cdot}6\mu$ for sylvine, for which up to the present time no experimental determinations have been made.

We employed a method based on the comparison of the grating spectrum and the prism spectrum which was similar to Langley's† method and which differed from it in only one point. While in Langley's arrangement the dispersion of the rays was obtained first from the grating and then from the prism under examination, in our arrangement the dispersion was brought about in the inverse order. This change was of little importance and was effected by us only because in that way we were able to set up our apparatus more conveniently.

1.



The arrangement of our apparatus is given in figure 1. In it *a* represents the source of heat (Linnemann zircon burner)

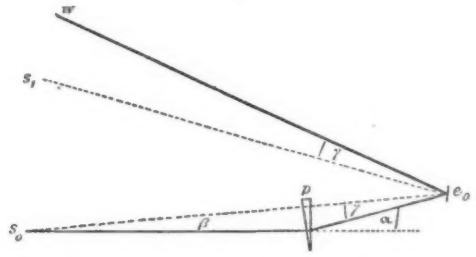
* H. Rubens and E. F. Nichols, Wied. Ann., l, p. 454, 1897.

† Langley, this Journal, xxvii, 169; Wied. Ann., xxii, p. 598, 1884.

and b, a concave mirror which concentrates the rays from a on the slit s_0. Behind the slit s_0 the rays traverse the sharp prism p, made of the substance to be examined, and fall on the concave mirror e_0. By means of this arrangement a spectrum is thrown in the plane of the slit of the spectrometer $s_1 e_1 e_2 s_2$, out of which spectrum the slit s_1 cuts a narrow band, the mean wave length of which can be varied at will by rotating the mirror e_0 about its vertical axis. On the table of the spectrometer $s_1 e_1 e_2 s_2$ a diffraction grating g of parallel silver wires was mounted for the measuring of the wave lengths of the rays passing through the slit s_1. The rays emerging from the fixed ocular slit s_2 were concentrated by means of a concave mirror of short focal distance on one wing of a Nichols radiometer.* The window of the radiometer was a chloride of silver plate, about 1^{mm} thick and the wings of the suspension were coated with iron oxide.

The spectrometer $s_1 e_1 e_2 s_2$ is the instrument whose construction and adjustment have been described at length in the above mentioned paper,† and we can in consequence refer to the description there given. However, it is necessary to enter more fully into the theory of the spectral arrangement, consisting of the slits s_0 and s_1, the prism p and the concave mirror e_0. Figure 2 represents the path of the middle ray when

2.



the deviation in the prism is 0 (as a dotted line) and, when the deviation is a (as a full line). In order that rays which are deviated in the prism p through the angle a shall fall in the slit s_1 it is necessary to turn the ray e_0 through the angle γ, that is, the mirror e_0 through the angle $\frac{\gamma}{2}$. But $\gamma = a - \beta$ and approximately $\beta : \gamma = e_0 p : p s_0$—hence $\gamma = a(p s_0 / s_0 e_0)$. The fraction $p s_0 / s_0 e_0$ can be easily determined by measurement to

* E. F. Nichols, Berliner Berichte, p. 1184; Wied. Ann., lx, p. 403, 1897 Physical Review, vol. iv, No. 22, p. 298, 1897.

† Rubens and Nichols, Wied. Ann., lx, p. 422, 1897.

within 0·2 per cent. Greater accuracy cannot be claimed for our measurements on dispersion.

It is evident that this arrangement is only applicable when the angle of the prism is very acute and the angles of deviation a are very small. In our case, the angles of the rock salt and sylvine prisms were approximately 12°; the observed deviations, between $4\frac{1}{2}°$ and 6°. With angles of this size the simple relation between γ, and a given above, already leads to errors in the deviation γ which may equal one minute. The error becomes, however, very much smaller by reckoning from the minimum deviation of the sodium line instead of from the deviation 0; namely, when one does not attempt the absolute measurement of the deviation a but confines oneself to the determination of the angle of dispersion $(a_D - a_\lambda)$. This is, in fact, entirely sufficient, for after determining this angle of dispersion, it is sufficient to know the deviation for the sodium line in order to calculate from this the deviations for all the observed wave lengths.

If the arrangement just described is used, then the error still present in the formula $\gamma_D - \gamma_\lambda = \text{const.}\,(a_D - a_\lambda)$ is very small and may be completely ignored, if a small correction is applied to the constant $\frac{e_0 p}{p s_0}$.*

The rotation of the mirror e_0 about its vertical axis was effected by means of a spectrometer on the table of which the mirror was mounted. The rotation of the table could be measured to within ten seconds on the graduated circle of the instrument by means of a vernier. As this accuracy was not sufficient for our purpose, we applied a divided micrometer head to the slow motion screw of the instrument, by means of which we were able to attain an accuracy of two seconds for small arcs. The prism p was set at minimum deviation for sodium light and kept throughout the work in this position. Therefore the application of the formula

* Strictly speaking $\beta = \gamma(e_0 p/p s_0)$ is not correct, the correct equation being

$$\beta = \text{arc. } tg\left\{\frac{e_0 p}{p s_0}\, tg\, \gamma\right\}$$

hence

$$\frac{\delta a}{\delta \gamma} = 1 + \frac{\frac{e_0 p}{p s_0}}{\cos^2\gamma + \left(\frac{e_0 p}{p s_0}\right)^2 \sin^2\gamma}.$$

If a mean value for γ, say 5°, be substituted in this equation, there appears in the place of the constant $e_0 s_0/p s_0$ a value for $\frac{\delta a}{\delta \gamma}$ which differs from the constant by 0·1 to 0·2 per cent.

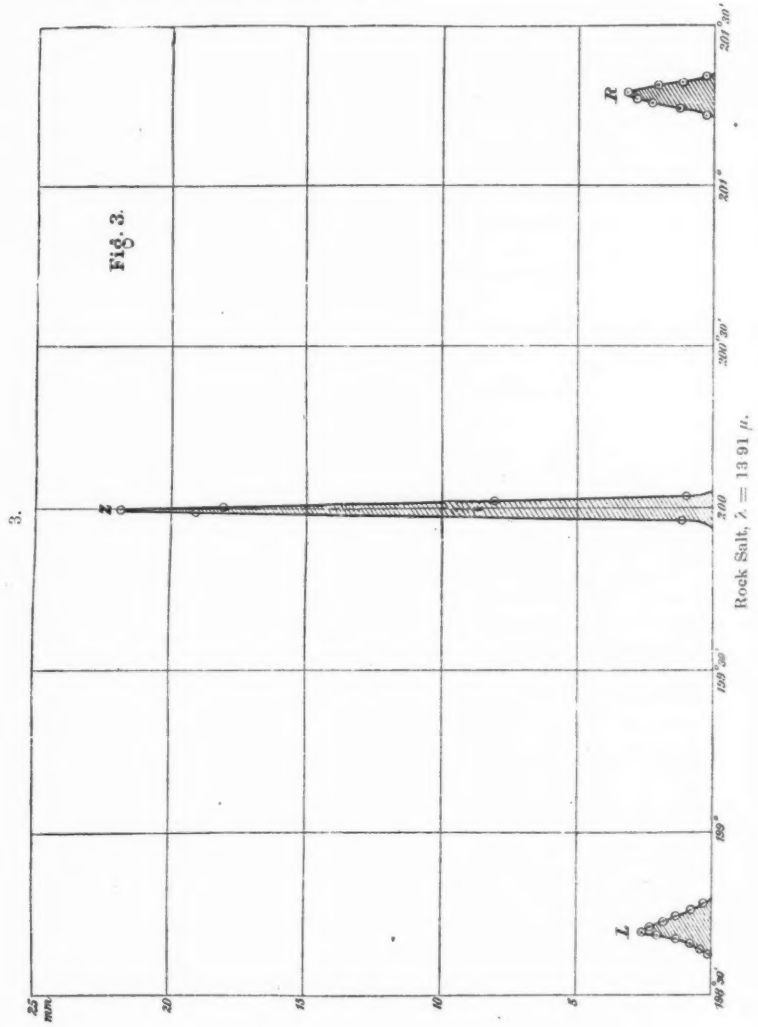
$$n = \frac{\sin \frac{\phi + \alpha}{2}}{\sin \frac{\phi}{2}}$$

to the examined portion of the infra-red spectrum, is not, strictly speaking, permissible, as this formula presupposes minimum deviation. Through calculation, however, it appears, that in our case the error is sufficiently small to be neglected, this being due to the acute angle of the prisms used.

This arrangement, consisting of the slit s_0, the concave mirror e_0, and the prism p, made it possible for us to throw on the slit of the spectrometer $s_1 e_1 e_2 s_2$, rays of known minimum deviation, and, as the angle of the prism had been previously determined, of given refractive index. The corresponding wave lengths were determined by means of the diffraction grating g. The properties and capabilities of this grating have been minutely enough described in the above mentioned communication* to permit us to omit further description. For the measurement of the wave length, both diffraction images of the first order were always located and the distribution of energy in both carefully determined in this way. We rotated the movable arm of the spectrometer a minute of arc at a time and each time carefully measured and noted the throw of the radiometer for the point in question. In figure 3 such a series for rock salt at the wave length $\lambda = 13{\cdot}91\mu$ is represented graphically. The readings on the divided circle of the spectrometer $s_1 e_1 e_2 s_2$ corresponding to the positions of the movable arm are plotted as abscissas, the corresponding throws of the radiometer as ordinates. It is noticeable that the diffraction images differ to a marked degree in distribution of energy. The right image is considerably narrower and higher than the left. This is not, as might be imagined, an accidental peculiarity of this series, due to inequalities in the intensity of the light source, but on the contrary is common to all the series observed by us. It is explained by the fact that the rays falling on the slit s_1 are not perfectly homogeneous, but are rather of different wave lengths; and, in fact, the distribution of the rays on the slit is such that (looking at the slit s_1 from the mirror e_0) those of shorter wave length fall on the right edge of the slit, those of greater wave length on the left. The same distribution of energy is apparent in the central image of fig. 3, only here right becomes left, and left right. Both the diffraction images appear widened with respect to the central image on account of the dispersion of the grating; however, the distribution of energy, already present in the central image, works on the two

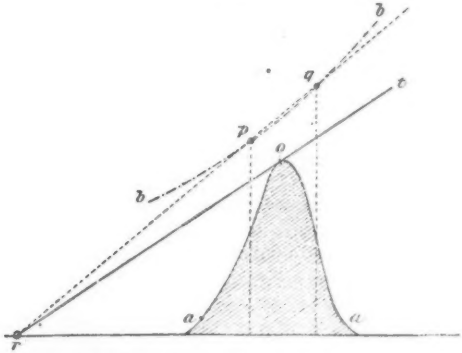
* Nichols and Rubens, Wied. Ann., lx, p. 425, 1897.

diffraction images in an opposite direction. Hence, the left image is more spread out, while the right one, from the same cause, becomes narrower and sharper, since in the first case the dispersions of both prism and grating are added, while in the second case, only the difference of the two dispersions has an effect, as in an achromatic lens.



Besides this asymmetry of form, there exists a slight but at the same time noticeable asymmetry of position of the two diffraction images with respect to the central image.* The total distance between the two diffraction images of the first order, remains, nevertheless, unchanged. On the other hand, a correction for the position of the maximum of the diffraction spectrum is necessary, for the reason that the rays of shorter wave length, falling on the slit s_1, possess greater energy than those of greater wave length. Because of this, the maximum in both images appears displaced toward the side of the shorter waves.

4.



In order to apply this correction, it is necessary to know the distribution of energy in the spectrum thrown from the source of light with the aid of the slit s_0, the prism p, and the mirror e_0. This was therefore carefully measured in each separate case with a special series of observations, and by means of the data so obtained, the angle of diffraction was determined at which the maximum of energy should appear, if the spectrum thrown in the plane of the slit s_1 possessed the same amount of energy at all points. This determination is easiest made by using a tangential construction given by Paschen,† the details of which are given in figure 4. The curve a represents the intensity curve of a diffraction image; the curve b gives the distribution of energy in the spectrum thrown in the plane of the slit s_1. Let i and i_1 be two ordinates of the curve b near the maximum of the curve a, and join the points p and q on the curve b corresponding to these ordinates, with a straight line which shall cut the axis of abscissas in a point r, and lay a

* The cause of the presence of this asymmetry lies in the arrangement of the spectrometer $s_1\, e_1\, e_2\, s_2$, Rubens and Nichols, Wied. Ann., lx, p. 422, 1897.

† F. Paschen, Wied. Ann., li, p. 1, 1894.

tangent to the curve a through r; then the abscissa of the point of contact o of this tangent gives the corrected position of the maximum.

The construction given is only admissible if the curve a in its middle portion represents a comparatively clean spectrum; that is, if the width of the central image is considerably less than that of the diffraction image. It is apparent, on considering this point, that this construction may be applied in all cases in which the size of the correction does not equal half the difference between the width of the central image and that of the diffraction image. In making the measurements given below, this limit was never exceeded. The size of the correction differed for each image, corresponding to the different width of each. On the right image it was only a few seconds; on the left in some cases more than a minute. If the slit s_1 were infinitely narrow, s_0 and s_2 having a finite width, both refraction images would appear of equal width, and the correction would be in both cases the same; that is to say, it would be, approximately, the arithmetical mean of the corrections applied by us on the right and left image. We have convinced ourselves of the correctness of this explanation by observations in which, under otherwise similar conditions, the width of the bilateral slit s_1 was varied between the limits $0{\cdot}2^{mm}$ and $0{\cdot}5^{mm}$. Here no systematic difference in the results was noticeable.

At the beginning of each series of observations the slit s_0 was illuminated with sodium light and the mirror e_0 was adjusted so that the sodium line fell exactly in the middle of the slit s_1. As the accuracy of the objective adjustment was found to be insufficient, we substituted an ocular of high power for the slit s_2, and by this subjective method, were able to adjust the sodium line on the slit s_1 with an accuracy of two seconds of arc. After this adjustment, the mirror e_0 was turned by means of the slow motion screw, through an angle $\delta = \frac{1}{2}(\gamma_D - \gamma_\lambda)$ which corresponded to a change in the minimum deviation of $a_D - a_\lambda$. The wave length was then measured in the manner given above.

The following two tables give the results obtained with a rock salt prism (angle $\phi = 10^\circ\ 53'\ 0''$) and a sylvine prism ($\phi = 12^\circ\ 39'\ 10''$) together with several indices of refraction and wave lengths taken from the two communications already cited.* The figures of the first column represent the differences between the minimum deviation a_λ for the wave length in question λ, and the minimum deviation of the sodium line

* The series marked with one asterisk * are taken from the work of Rubens; those marked with two asterisks from that of Rubens and Nichols.

a_D. The second column gives the corresponding indices of refraction. In the third are the observed wave lengths of the rays without the application of the correction mentioned above, and in the fourth, the same, corrected. In the fifth column are the values of the wave lengths for the corresponding indices of refraction, calculated from the Ketteler-Helmholtz formula, using the constants given by Mr. Nichols and one of us.

TABLE I.

Rock salt $\phi = 10° 53' 00''$

$a_D - a_\lambda$	n	λ uncorrected.	λ corrected.	λ calculated.
----	1·5441*	0·589μ	----	0·589
----	1·5030*	8·67	----	8·67
32′ 19″	1·4951	9·88	9·95μ	10·00
41 55	1·4805	11·85	11·88	12 00
53 39	1·4627	13·94	13·96	14 00
1° 7′ 55″	1·4410	15·81	15·89	16·00
1 25 9	1·4148	17·87	17·93	18 00
	1·3735**	20·57	----	20·57
	1 3403**	22·3	----	22·3

$b^2 = 5·1790$, $M_1 = 0·018\,496$, $M_2 = 8977·0$, $\lambda_1^2 = 0·01621$, $\lambda_2^2 = 3149·3$.

TABLE II.

Sylvine $\phi = 12° 39' 10''$.

$a_D - a_\lambda$	n	λ uncorrected.	λ corrected.	λ calculated.
----	1·4900*	0·589μ	----	0·587μ
----	1·4653*	7·08	----	7·08
26′ 2″	1·4561	9·94	10·01μ	10·00
41 40	1·4362	13·88	14·14	14·20
1° 1 7	1·4102	17·94	18·10	18·05
----	1·3882**	20·60	----	20·60
----	1·3692**	22·5	----	22 5

$b_2^2 = 4·5531$, $M_1 = 0·0150$, $\lambda_1^2 = 0·0234$, $M_2 = 10747$, $\lambda_2^2 = 4517·1$.

The calculated values of the wave lengths are, for both substances, almost without exception, larger than the observed values; however, the difference is, for the most part, less than $\frac{1}{2}$ per cent. and this $\frac{1}{2}$ per cent lies generally within the limit of error in observation, which must be estimated at from 0·3 to 0·7 per cent. Therefore the equation for the dispersion satisfies the demands made on it in the portion of the spectrum between $\lambda = 10\mu$ and $\lambda = 20\mu$.

*H. Rubens, Berichte der Physikal. Gesellschaft, 6 Nov., 1896.

Measurement of the Absorption.

Several measurements were made a short time ago by one of us, touching on the infra-red absorption spectrum of rock salt and sylvine. A diffraction grating served to produce the spectrum. A zircon lamp was used as a heat source, the rays of which had to pass, before their entrance into the spectrometer, through a thin lamp-blacked chloride of silver plate, whereby the disturbing energy from rays of shorter wave length was removed. In order to overcome the influence of the spectra of higher order, the throws of the bolometer were always observed in the following manner. A fluorite plate 6^{mm} thick was slid into the path of the rays, and after the completion of the throw, again removed. This fluorite plate absorbed completely only the long waves of the spectrum of the first order (12 to 20μ), while it let through the short waves of the spectra of higher order unweakened, except for the loss of strength due to reflection. The results on the absorption of rock salt and sylvine plates, obtained in this manner, could, on account of the exceedingly small amount of energy in the diffraction spectrum, lay no claims to great accuracy and were of service only as a forerunner of more careful determination. On the other hand, it was possible for us, with the use of the above mentioned acute-angled prisms made of rock salt and sylvine, to produce a doubly dispersed, continuous spectrum which was sufficiently intense and pure, to make possible the measurement of absorption for both substances. To this end, the grating g was removed from the table of the spectrometer $s_1 e_1 e_2 s_2$, and in its place the rock salt prism was set up, so that it gave the minimum of deviation for the sodium line. In the adjustment of the apparatus for a given wave length, the mirror e_0 as well as the moveable arm of the spectrometer $s_1 e_1 e_2 s_2$, was turned through the proper angle, the value of which, in each case, was calculated from the dispersion of the prisms and the constants of the apparatus.

The plates, the absorption of which was to be determined, were placed directly before the slit s_0 in the path of the rays, by means of a sliding holder. Near the slit s_1 was a shutter, worked with cord and pulley, which could be set from the observer's table so that it either let through or shut off from the slit s_1 the rays coming from the mirror e_0. This shutter consisted of a plane-parallel glass plate 2^{mm} thick, which let through about 75% of the total radiation of the zircon lamp, but absorbed completely the rays in the field between $\lambda = 8\mu$ and $\lambda = 21\mu$, in which we worked. The advantage which lies in the use of such a glass plate instead of a metal shutter is that the diffuse radiant heat of short wave lengths (the maximum of emission of the zircon lamp lies at about $1{\cdot}4\mu$) which may

be present in the infra-red part of the spectrum, works for the most part, continually on the radiometer, and therefore becomes harmless for the observations.

Because of the small dispersion of our prisms, we could, in our experiments, only determine the general trend of the absorption. In the field between $\lambda = 9{\cdot}0\mu$ and $\lambda = 20{\cdot}75\mu$, measurements were taken at twelve different points, on the absorption of a rock salt layer $23{\cdot}3^{mm}$ thick and a sylvine layer $10{\cdot}7^{mm}$ thick by placing alternately a thick and a thin plate of the material to be examined, in front of the slit s_0. The ratio of the throws of the radiometer, observed in both cases, gives the transmission for a layer, the thickness of which is equal to the difference in thickness of the two plates.*

In this way the following results were obtained:

TABLE III.

Wave length. λ	Rock salt $d = 23{\cdot}3^{mm}$	Sylvine. $d = 10{\cdot}7^{mm}$	Wave length. λ	Rock salt. $d = 23{\cdot}3^{mm}$	Sylvine. $d = 10{\cdot}7^{mm}$
9μ	98·8	100·2	16μ	38·1	93·1
10	98·7	98·6	17	21·4	91·6
11	98·9	98·9	18	4·94	85·3
12	98·3	99·4	19	0·1	74·3
13	94·4	99·4	20·7	----	56·3
14	84·7	97·3	23·7	----	13·5
15	67·8	95·0			

In another table we give our results on the transmission of a rock salt plate, a chloride of silver plate† and a fluorite plate, which were obtained by comparison of the direct and transmitted energies. In order to calculate the absorption of the plates, the influence of the reflection must be eliminated from these numbers.

With the help of the figures given in Table III, the following values (Table V) were obtained for the transmission of layers of rock salt and sylvine 1^{cm} thick. For rock salt, from $\lambda = 19\mu$ on, Table V was filled in with the results from Table IV. Similarly, the values given for fluorite were calculated from the values given in Table IV, after using Paschen's measurements on dispersion in eliminating from them the loss of energy due to reflection.

*Since the absorption in rock salt was very considerable beyond 19μ we used only the sylvine prism for the wave lengths $\lambda = 20$, 7μ and $\lambda = 23{\cdot}7\mu$, making the rays monochromatic, before their entrance into the slit s_0, by successive reflection on quartz ($\lambda = 20{\cdot}7\mu$) and on fluorite ($\lambda = 23{\cdot}7\mu$).

†The chloride of silver plate used by us is one of those which Schultze-Sellack prepared and tested for transmission of heat rays in 1870.—Pogg. Ann., cxxxix, p. 182, 1870.

TABLE IV.

Wave length. λ	Fluorite $d = 3{\cdot}40$.	Chloride of silver. $d = 3{\cdot}08$.	Rock salt. $d = 3{\cdot}77$.
8μ	89·5	40·5	92·0
9	77·0	44·8	91·5
10	51·5	51·5	90·9
11	19·8	55 0	92·0
12	2·07	57·8	92·0
13	0·0	59·2	90·5
14	----	60·2	90·5
15	----	59·9	89·5
16	----	63·8	85·6
17	----	67·8	74·7
18	----	----	63·7
19	----	67·9	39·1
20·7	----	64·7	13·4
23·7	----	28·0	1·1

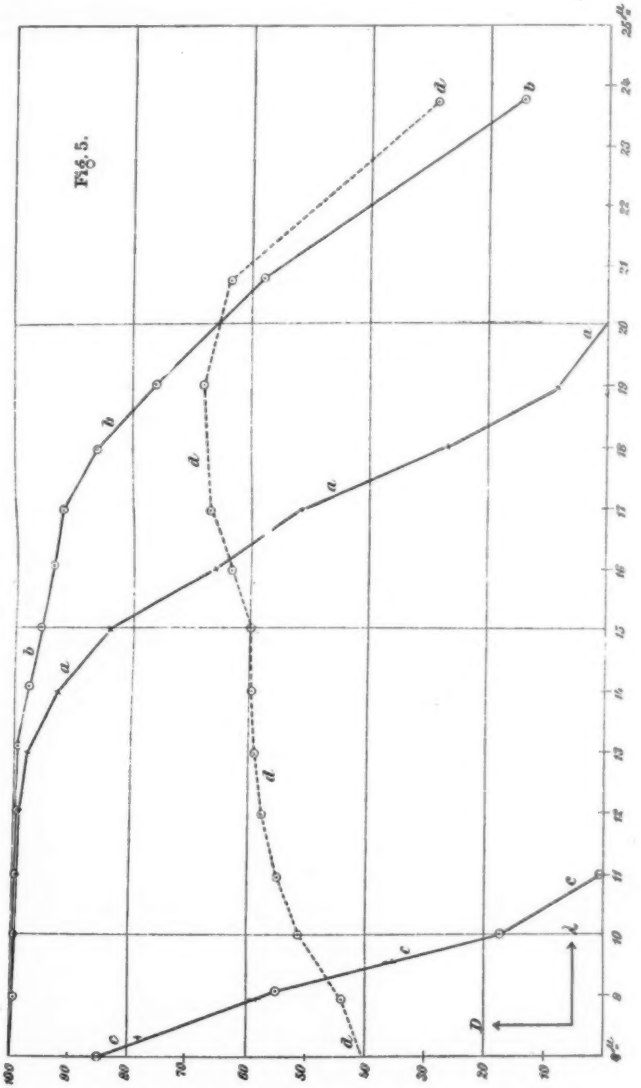
TABLE V.

Wave length λ.	Rock-salt.	Sylvine.	Fluorite.
	Thickness of layer = 1^{cm}		
8μ	----	----	84·4
9	99 5	100·2	54·3
10	99·5	98·8	16·4
11	99·5	99·0	1·0
12	99·3	99·5	0·0
13	97·6	99·5	----
14	93·1	97·5	----
15	84·6	95·4	----
16	66·1	93·6	----
17	51·6	92·2	----
18	27·5	86·2	----
19	9·6	75·8	----
20·7	0·6	58·5	----
23·7	----	15·5	----

On the other hand, we did not calculate values for a layer of chloride of silver 1^{cm} thick, as the chloride of silver plates used by us were not sufficiently clear and homogeneous to seem to us to permit of the application of the law of absorption, with even the roughest approximation. For light rays, the plate was almost completely turbid, so that the increase in its transmission for increasing wave lengths in the field between $\lambda = 8\mu$ and $\lambda = 18\mu$, may possibly be only attributable to the similar* peculiarities observed by Ångström for turbid media. The transmission, as a function of the wave length, of a layer 1^{cm} thick of rock salt, sylvine, and fluorite, is given

* K. Ångström, Wied. Ann., xxxvi, p. 715, 1889.

5.



graphically in figure 5. The curves show in all three cases a very similar character. We notice that rock salt (curve *a*)

already shows a visible absorption at 12μ for this thickness of layer, and that beyond 20μ the absorption is almost complete. Sylvine (curve *b*) begins first to absorb to a marked degree beyond 13μ and still shows even at $\lambda = 23{\cdot}7\mu$ the same transmission that rock salt shows at $\lambda = 18{\cdot}5\mu$. The curve of transmission for fluorite falls sharply and touches the axis of abscissas close beyond $\lambda = 11\mu$. Paschen* has also examined, in the communication cited above, the absorption of a fluorite plate to the wave length $\lambda = 9{\cdot}43\mu$. If the transmission of a layer 1^{cm} thick is calculated from the data obtained by him, and the points are plotted in fig. 5, they show a very good agreement with the points observed by us. In order to distinguish between the points calculated from Mr. Paschen's values and those obtained from our results, the former have been plotted as crosses (+) and the latter as circles ($\odot$).

This agreement furnishes at the same time a proof of the pureness of our spectrum and of the correctness of our measurements on the dispersion of the rock salt and sylvine prisms.†

The dotted line (*a*) in fig. 5 gives the transmission of the chloride of silver plate 3^{mm} thick as a function of the wave length. A correction for the loss of energy due to reflection has not been applied to it.

In reviewing the results communicated in this paper, the conclusion is reached that it is possible with double dispersion, using two acute-angled prisms made of rock salt, to obtain sufficient energy in the infra-red spectrum out as far as $\lambda = 18\mu$, and that using sylvine prisms, one may attain to still greater wave lengths (about $\lambda = 23\mu$). To be sure, the amount of energy obtained after this method is much less than that obtained by repeated reflection on quartz or fluorite surfaces.

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* F. Paschen, Wied. Ann., li, p. 333.

† As a further test of the correctness of our measurements on dispersion, we took, in the above mentioned manner, measurements on the dispersion in an acute angled fluorite prism in the field between $\mu = 9{\cdot}0\mu$ and $\lambda = 10{\cdot}0\mu$ which were in good agreement with Mr. Paschen's results. The greatest departure from his values was 0·4 per cent in the wave length.

ART. VI.—*Studies in the Cyperaceæ;* by THEO. HOLM. VII. On the inflorescence of the genus *Scleria*. With figures in the text.

THIS genus was first established by Bergius upon some plants, which Rolander collected in Surinam in the year 1755. But some species of this same genus were known to earlier authors, as appears from certain descriptions and figures, though previous to Bergius, no attempt had been made to separate these plants as generically distinct from other *Cyperaceæ*. Thus Rheede, as early as the year 1686, figured a plant, which Dillwyn identified with *Scleria lithosperma;* Morison's "Cyperus Americanus major Lithospermi semine" seems also to represent some species of *Scleria*, while Plukenet's plant "Gramen cyperoides Lithospermi semine, Virginianum" is of rather doubtful relationship. But Sloane described and figured a true *Scleria* from Jamaica, and Elmgren's "Schœnus secans" belongs undoubtedly to this genus. No further record seems to have been given of this peculiar genus, for which Bergius selected the name "*Scleria*."

We might state at the same time, that the derivation of the name, commonly given as "σκληρία, hardness, from the indurated fruit," is not correct. It is derived from σκληρός in the sense of severe and merciless, since Bergius states that his species *Scleria Flagellum nigrorum* was used as a whip for the punishment of slaves in Surinam. The stems of this species are exceedingly sharp-angled and prickly, and tied together they formed a most cruel and painful instrument of punishment, hence the derivation from σκληρός.

Examining the generic diagnosis given by Bergius, it is interesting to notice that he observed the perigynium, alluding to it in the following words: "Semen, basi cinctum perichætio membranaceo, ciliato-setaceo." This term "perichætium" was adopted by Bischoff for those membranaceous or setaceous organs which are often observed in female flowers of certain plants. Besides this, Bergius mentions the distichous bracts, the bony, snow-white fruit and the unisexual flowers, which characters are perfectly sufficient for the establishment of the genus. Most peculiar is the structure of the so-called perigynium or discus of the female flower, which Eichler thought might represent abortive stamens. It shows great differences of structure in the various species. In *Scleria pauciflora* Muhl. it is a low triangular disk upon which three pairs of minute wart-like organs are to be observed. We might

define these organs as representing two whorls of rudimentary leaves, three in the exterior and six in the interior whorl, corresponding to Boeckeler's "perigynium duplex." This perigynium varies greatly, as we have stated above. In *S. reticularis* Michx. there are only three, but very distinct, lobes in the inner whorl, while in *S triglomerata* Michx. these organs are reduced to a minutely papillose cupule. It is, also, to be noted, that while the inferior disk remains with the bracts, the superior falls off with the fruit. The presence of these two whorls of rudimentary organs might warrant the supposition that they represent formations analogous to the dimorphous perianth-leaves, which we described in another article as characteristic of *Fuirena squarrosa* and *scirpoidea*. We feel inclined to consider these organs as perianth leaves, rather than abortive stamens, inasmuch as the male flower in this genus has but three stamens, or sometimes two or even one only.* A double whorl of true stamens is, according to Pax known only in the genera *Reedia*, *Lepidosperma*, *Elynanthus*, *Evandra* and in a few species of *Gahnia* and *Lamprocarya*.

In regard to the bracts, which belong to the male and female inflorescences, we can state that in *Scleria pauciflora* Muhl. the male spikes are composed of several spirally arranged bracts, each of which subtends a staminate flower, while the one-flowered female spike bears constantly three distichous bracts, of which the two lower ones are empty. In the androgynous spikes the basal female flower is preceded by only one empty bract. It is to be noted, furthermore, that the distichous arrangement of the bracts in the female spike is transverse to that of the supporting leaf, and that the first empty bract succeeding the prophyllon is placed to the right of the rhachis, which is to be seen from the accompanying diagram (fig. 1).

None of the flowers possess any prophyllon, but a clado-prophyllon is constantly developed at the base of each lateral peduncle. This is very short, membranaceous, often emarginate and surrounds the peduncle with its free margins. Examining the inflorescence of *S. pauciflora*, we notice that the flowers are all arranged in spikes, forming together a more or less decompound inflorescence. These spikes may be situated at the apex of the stem, supported by green leaf-like bracts, or there may also be developed a secondary inflorescence from the axil of one of the lower situated stem-leaves. The composi-

* The male flower is generally described as having from one to two stamens; this statement is, however, not correct, since we have observed three normally developed stamens in our North American species with the exception of *S. reticularis* Michx. and *S. Torreyana* Walp., in which we have only found two.

tion of the inflorescence is, however, the same whether it is developed near the apex or the base of the stem.

While our plant is not commonly dioecious, the flowers show a tendency to develop in separate spikes, as wholly male, as wholly female, or as androgynous. Of these the male spikes are always many-flowered but with an extremely short rhachis, while the female have merely one flower. The androgynous ones are composed of several male and one single female flower, which is situated at the base of the spike. As regards the distribution of the sexes, the male spikes are usually gathered at the apex of the inflorescence, terminating the main stem or the lateral branches. Exclusively male plants have not been observed, though we have found several specimens with only female flowers developed, at the same time as the basal inflorescences of monœcious specimens were noticed to be exclusively female. Neutral flowers (reduced females) may accidentally be found in copious-flowered specimens.

1.

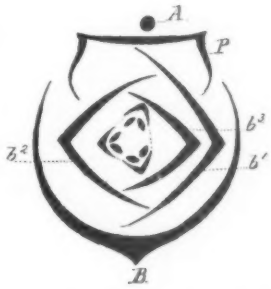

FIG. 1. Diagram of a female spike of *Scleria pauciflora* Muhl. A = the axis; B = the leafy bract, which subtends the spike; P = prophyllon: b^1 and b^2 = empty bracts, b^3 = bract subtending the female flower, of which the two whorls of the perianth has been drawn.

A characteristic divergence between the male and female spikes lies in the development of the foliar organs, the bracts, which we have already indicated above. The male flower is subtended by a scale-like bract, which is not preceded by any empty ones, while such occur in the number of two in the female spikes, or of only one in the androgynous. Another and very striking character is that of a spiral arrangement of bracts in the male spike, in contrast to the biseriate arrangement of the same organs in the female.

Essaying to demonstrate the general structure of the inflorescence in *Scleria pauciflora*, we may begin with one of the very small lateral ones, which often developed from the axil of the lower stem-leaves.

The accompanying figure 2 represents one of these lateral inflorescences, borne upon a long, slender peduncle (St.), upon which two leaf-like bracts (B^1 and B^2) are to be seen. In the axil of the first bract (B^1) is developed a one-flowered female spike, borne upon a very short peduncle with its prophyllon (P) at the base. This spike consists of two empty bracts (b^1 and b^2), preceding a third (b^3) which subtends the pistillate flower. The first of these bracts (b^1) is usually narrow and almost awl-shaped, while the inner ones are much broader and

distinctly carinate. The bracts as well as the peduncle are more or less hairy, but we have not figured these hairs, since they would make the details of the spikes less distinct. Behind this axillary spike is another one to be seen, which terminates the peduncle and which, therefore, lacks the prophyllon. Just above the bract (B^2) is a short internode, upon which three scale-like bracts follow (b^1, b^2 and b^3), the innermost of which encloses an almost mature fruit with its characteristic white and warty pericarp. The composition of the female spike becomes then merely reduced to a short rhachis, bearing three distichous bracts and a single flower, which has developed from the axil of the innermost bract. It might appear, according to this and similar depauperate inflorescences, as if the female flower were actually terminal, inasmuch as no rudimentary elongation of the rhachis was to be observed, but in view of the androgynous spikes, it seems most natural to suppose that the flower is axillary rather than terminal. As already stated, some specimens have been observed to be exclusively female, and these showed an arrangement of the flowers corresponding to that above described (figure 2), with the exception that a larger number, three or four, spikes were developed. When the spike is androgynous, the female flower is constantly situated in the axil of the second bract (b^2) as shown in our figure 3, while the first male flower (S) develops in the axil of the third bract (b^3). This last bract attains a larger size than in the female spikes, while the succeeding bracts, all subtending male flowers, decrease in size and texture, the innermost being very narrow and membranaceous. The female flower is thus preceded by only one empty bract in the androgynous spikes, and the first male flower appears immediately within the third bract. This circumstance seems to support our theory of the female flower as being axillary and not terminal. The biseriate arrangement of the bracts in the female spike

2.

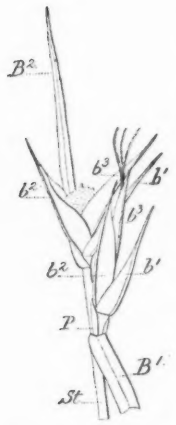

FIG. 2. Basal inflorescence of *S. pauciflora*. Explanation in the text.

3.

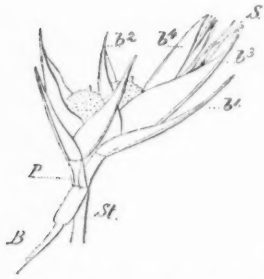

FIG. 3. A female and an androgynous spike of *Scleria pauciflora*. Explanation in the text.

recurs in the androgynous at least as far as concerns the lower four (b^1–b^4).

Having examined now the minor inflorescences as they occur in *Scleria pauciflora*, we may transpose these to the larger and fully developed, of which a representation is given in the accompanying figure 4. It may at a first glance seem somewhat difficult to separate the constituents of these fasciculate spikes, but if we bear in mind, that a prophyllon (P) is developed on each of the lateral branches and that the bracts of the pistillate spikes are distichous, the composition of the inflorescence becomes much simplified. Our figure shows the presence of four leafy bracts (B^1–B^4) each of which subtends lateral inflorescences, decompound or single. The peduncle, which has developed in the axil of the bract, B^1, bears a prophyllon (P) and a bract (B^2), which latter subtends a very short peduncle with a young pistillate spike, while a mature female terminates the main peduncle, developed from the axil of the bract (B^1). The same becomes repeated if we consider the succeeding inflorescence in the axil of the bract above (B^2). Also here are two spikes, the lateral being very young and exclusively female, the terminal on the contrary androgynous and mature. A single wholly male spike is developed in the axil of the uppermost bract (B^4), and we notice here the usual prophyllon, but no empty bracts. The terminal spike is androgynous and exhibits the same structure shown in our figure 3.

4.

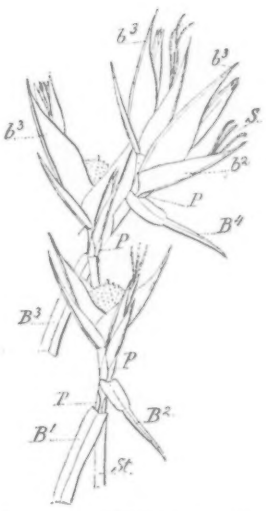

FIG. 4. Inflorescence of *S. pauciflora*. Explanation in the text.

This form of inflorescence seems to be characteristic of the most common North American species of *Scleria*, viz: *S. pauciflora* Muhl. and *S. triglomerata* Michx., besides that we have, also, observed it in *S. ciliata* Michx. and *S. oligantha* Michx. The arrangement of the spikes is principally the same in two other species, *S. reticularis* Michx. and *S. Torreyana* Walp., but the structure of their spikes is somewhat different. There are no androgynous spikes in these two species, but the staminate one (fig. 5) has three empty bracts (b^1–b^3), which exhibit a distinctly biseriate arrangement like those of the pistillate spike, with which they furthermore agree in size and shape; but no rudiment of any flower was found within these.

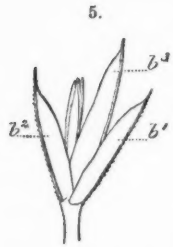

Fig. 5. Staminate spike of *S reticularis*. Explanation in text.

The inflorescence of *S. Baldwini* Steud. and *S. gracilis* Ell. is principally the same as we have described for *S. pauciflora* Muhl., with the only exception that the spikes are here gathered in compact fascicles at the apex of the stem. *Scleria hirtella* Swtz. and *S. verticillata* Muhl. exhibit, on the other hand, a very different position of the spikes, since these are here situated in sessile, roundish fascicles along the stem with the subtending bracts very short and bristle-shaped. Otherwise the minor structure of the spikes is the same as described for *S. pauciflora*.

The North American representatives of our genus show thus a very uniform arrangement of flowers and minor inflorescences, and they belong to the group "Spicatæ" of Boeckeler (l. c.), well distinguished from the other groups "Paniculatæ" and "Corymbosæ." The structure of the inflorescence in our species of *Scleria* does not therefore furnish characters sufficient for the distinguishing of species. Such characters must be sought in the shape and structure of the pericarp, and in the peculiar perianth, both of which have been described so very carefully by Bœckeler in his work, to which we have so often referred.

Washington, D. C., June, 1897.

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Art. VII.—*X-Rays and Mineral Phosphorescence;* by John E. Burbank.

In January, 1897, while experimenting at Bowdoin College on fluorescent screens for the X-rays, the attention of the writer was attracted by the fluorescence of minerals under the action of these rays.

Doubtless others have experimented on this subject, but the writer has been unable to find more than a brief note stating the mere fact of fluorescence under action of X-rays. Some of the following results, therefore, may be of interest. Fluorite when exposed to X-rays phosphoresces with a bluish white light which continues for a very long time after being removed from the influence of X-rays. It has been placed by some experimenters under the photographic place in radiography, to increase the effect of the X-rays; but unfortunately it fogs the plate and blurs the outline of the image.

Very many minerals were tried and more than two-thirds were found to be phosphorescent to a greater or less degree. The group of minerals containing Ca were most susceptible to the X-rays. Of 16 specimens tried 12 were phosphorescent, with light varying from pure white to yellowish red. The feldspar group is also susceptible, also others of the silicates; but in general minerals containing ores of the metals are non-phosphorescent.

Of all substances tried fluorite and calcite seemed the most suitable for experimentation, and all the experiments were performed with these minerals, outside the X-ray tube, in a perfectly dark room. It is well known that both light and heat radiations can produce luminous effects in the case of mineral crystals, and these effects are very much like those produced by X-rays; at least far as the eyes can judge; but if we heat the crystals and then expose them to the radiations coming from an X-ray tube, the character of the light is often changed. For example:

Glass, which fluoresces bluish, if sufficiently heated loses its power while hot; but as it cools the light can be seen slowly creeping back over it; when cool it regains its former condition.

With fluorite the effect is similar except that the light, instead of disappearing, is weakened and fades out sooner than that from the unheated, when removed from the influence of the X-rays. If fluorite is heated very hot the phosphorescent light is very much weakened.

With calcite, which phosphoresces a pale reddish yellow, the effect of heat is to brighten very much the light emitted, and

to change its color to white. The effect of heat is very striking with calcite which has been heated to redness and allowed to cool so that it is just invisible; then when exposed side by side with the unheated it is nearly twice as bright as the latter. On cooling it regains its former color and intensity of radiation.

The effect of heat on other crystals in some cases causes increased emission of light, in others diminished effect, and in several cases no effect was observed.

Jefferson Physical Laboratory, Harvard University.

Art. VIII.—*Phosphorescence produced by Electrification;* by John Trowbridge and John E. Burbank.

Various investigators have stated that the X-rays can communicate an electrical charge to bodies. We were interested to discover whether this statement could be verified by means of the phenomena of phosphorescence. When fluorite, in the state of a comparatively coarse powder, is heated to a low red heat for about an hour, it loses completely its power of phosphorescing under the effect of a low red heat; if it is then electrified by means of the brush discharge of an electrical machine, and then submitted to a low red heat, it suddenly phosphoresces. In this connection it is interesting to note a statement of E. Becquerel upon the effect of electric sparks on phosphorescent bodies. In his work entitled "La lumière ses Causes et ses Effects,"* he says, "In order to submit the substances to the action of electric discharges they were placed directly upon an insulated stand, if they were in fragments—or in tubes if they were in the state of powder—in such a manner that the discharge terminals were two or three centimeters apart. One or many electrical discharges are then passed from Leyden jars between the terminals. We then find that not only the bodies in question become phosphorescent after the passage of the discharge; but also, as is seen later, they are made phosphorescent by these electrical discharges when subjected to heat, even if before having been submitted to the action of the discharges, they had been calcined so long as to be entirely deprived of the power of phosphorescence by elevation of temperature. The electric light acts, therefore, like sunlight, but with greater energy by reason of its greater intensity on account of the position of the bodies; and it is capable of making bodies acquire phosphorescence which did not previously possess it. There is no necessity of submitting fluorspar or the diamond to heat immediately after having been exposed to the discharges. The elevation of temperature can take place even after the lapse of some months?"

Becquerel evidently attributed the effects observed to the light of the discharge, for he says further, p. 55 id., "The electric spark acts only by its light, but its action is more energetic than that of sunlight by reason of its great intensity and the proximity of the source."

In an article on luminescence by E. Wiedemann and G. C. Schmidt the conclusion is reached that the violet light alone of

* Paris, 1897, p. 55.

electrical discharges does not cause phosphorescence; but the phosphorescence is due to peculiar discharge rays analogous to cathode rays.* M. W. Hoffmann has confirmed Wiedemann's work.† The latter states that no "Entladungsstrahlen" could be detected in the brush discharge.

With the preparation of fluorite, we have mentioned above, no effect was produced by the light of the electrical discharge. It was submitted, according to the method of Becquerel, to the light of the spark; and it was also exposed to the light of burning magnesium, and to that of the voltaic arc; and no direct phosphorescent effects could be produced, nor by subsequent heating. It phosphoresced, however, on heating after having been electrified by the brush discharge. The phosphorescence was evidently an expression of the electrical energy, which was communicated to the substance, and this energy was suddenly converted into light by the action of the heat in dispelling the electricity. The substance was next subjected to the action of the X-rays, in a brass box, closed by an aluminum window. The box was also connected to the ground. When the substance was taken from the metallic box it showed no phosphorescence, but on being heated it exhibited a bright phosphorescence which quickly disappeared.

The action of the X-rays on this mineral was exactly similar to that of electrification; and we cannot but regard our experiments as an evidence of the electrical nature of the action of the X-rays. By them an electrical charge is communicated to a fluorescent and phosphorescent substances. The resulting electrical energy, in being dissipated, produces the phenomenon of light. By heating crystals which have been electrified, we produce a sudden dissipation of the electrical energy which has been communicated to the particles of the phosphorescent substance—either by direct electrification or by the electrification produced by the X-rays.

Most phosphorescent substances, after having been submitted to sunlight or daylight, glow more strongly when heated. The phosphorescence, however, dies out quicker after the process of heating, which seems to cause the energy communicated to the substance by light to become dissipated more quickly. The same thing is true of the state of phosphorescence communicated by the X-rays. Can we, therefore, conclude that the phosphorescence excited by sunlight or daylight is due to an electrical condition which can be dissipated by heat? This supposition seems to us not inconsistent with the electromagnetic theory of light, and phosphorescence may be an evidence of the electrical stresses which produce the phenomena of ultraviolet light.

Jefferson Physical Laboratory, Harvard University.

* Wied. Ann., lvi, 1895, p. 237. † Wied. Ann., No. 2, 1897, p. 273.

ART. IX.—*Electromotive Force;* by JOHN TROWBRIDGE.

LORD KELVIN in a paper dated April 12, 1860,* entitled Measurement of Electromotive Force required to produce a spark, states that "there is a much less rapid variation with distance of the electrostatic force preceding a spark at the greater than at the smaller distance. It seems most probable that at still greater distances the electrostatic force will be found to be sensibly constant, as it was certainly expected to be at all distances."

Having at my command a very much improved Planté rheostatic machine with sixty condensers of 15x80 inches coated surface, I have been enabled to greatly extend my studies of high electromotive force, and to investigate the conditions necessary to produce sparks of great body and forty-eight to fifty inches in length. The accumulator which was used to charge the rheostatic machine in parallel had a voltage of 20,000, and the machine could then give me 1,200,000 volts. The length of spark which corresponds to the voltage is very closely forty-eight inches. Professor Elihu Thomson, by means of transformers, has obtained sparks of fifty to sixty inches in length, and has estimated the necessary voltage to produce a spark of 80^{cm} at 500,000.

This estimate A. Heydweiler† thinks is very much too great and he believes that 100,000 would be nearer the truth. My investigations show conclusively that the estimate of Professor Thomson is far nearer the truth than that of Heydweiler, and instead of being lessened it should be increased.

In a late paper on the tension at the poles of induction apparatus A. Oberbeck‡ states that a potential difference of 60,000 volts under given conditions can produce a spark of more than 10^{cm} in length. It is difficult to obtain consistent results by the use of induction coils and transformers.

My results show that Lord Kelvin's conjecture that the electrostatic force necessary to produce a spark in air remains sensibly constant for all distances beyond the limit he describes, is correct; for when the length of spark is plotted as abscissas and the corresponding electromotive force as ordinates a straight line is obtained. Planté calls attention to the fact that the loss of energy resulting from the transformation of dynamic into static electricity is in the case of his apparatus much less than in induction apparatus. This remark applies with great force to the modern use of transformers for the production of

* Papers on Electrostatics and Magnetism. Macmillan, London, 1872, p. 258.
† Wied. Ann., 48, p. 231, 1893. ‡ Wied. Ann., No. 9, p. 109, 1897.

high tension effects. With the improved form of rheostatic machine which I have had constructed, one-third of a horse-power will produce the effects which have hitherto required the employment of thirty to forty horse-power. The condensers in this apparatus were very uniform in thickness, and the charging and discharging method was a complete departure from that adopted by Planté. All forms of rotating cylinders carrying contact pieces were abandoned and two lever arms were used to charge the condensers in parallel and then to discharge in series. Great uniformity of action was thus secured. The spark produced by the apparatus have very great disruptive effects and produce a report like the discharge of a pistol. The electrostatic field in the neighborhood of the terminals is very intense, and the wires leading to the spark gap emit brush discharges which extend at least twelve inches from the surface of the wire. I was interested to observe the effect of such powerful discharges through Crookes's tubes, and therefore placed a tube which had been exhausted to such a degree that sparks eight inches in length preferred to pass through the air from terminal to terminal of the tube rather than to pass through the rarified space. The disruptive discharge produced by the machine passed readily through such a tube and showed the X-rays with great brilliancy; moreover the degree of rarifaction of the tube was not sensibly altered by single discharges of such high electromotive force.

The results so far obtained by the employment of this apparatus prove that the length of spark is proportional to electromotive force. Rarified spaces hitherto considered too high vacua to conduct electricity cease to act like such vacua to very high electromotive force.

Jefferson Physical Laboratory.

ART. X.—*Surface Travel on Electrolytes;* by W. E. FISKE and W. D. COLLINS.

To investigate the availability of Ohm's law for electrolytes when in circuit with alternating currents, has been the object of frequent research. The following are references to articles by Kohlrausch having a bearing on the subject: Pogg. Ann., cxxxviii, p. 370; Wied. Ann., vi, p. 1; xxvi, p. 164. Also in Wied. Ann., xxi, p. 667, E. Cohn gives an elaborate treatment of the matter. All these investigations showed that Ohm's law held in nearly every case, the only exception being that polarization at the electrodes seemed to increase the resistance slightly when the current was of a frequency as low as 100 or less per second. In view of the fact, however, that this work was in no case carried on with a current alternating more than 25,000 times per second, it seemed worth while to examine the resistance of an electrolyte to a current of much higher frequency.

The following work was carried on under the direction of Professor Trowbridge.

The method used was practically that described by Professors Trowbridge and Richards in an article in this Journal (vol. iii, p. 327, April, 1897). The electrolyte replaced the tubes of gas, and its resistance, together with that of the wires used for the standard, was measured with an alternating current.

The electrolyte, a saturated solution of copper sulphate, was contained in a tank a meter long and a square decimeter in cross-section. The electrodes were of sheet copper equaling in area the cross-section of the tank. The distance between them could easily be altered so as to give a column of variable resistance.

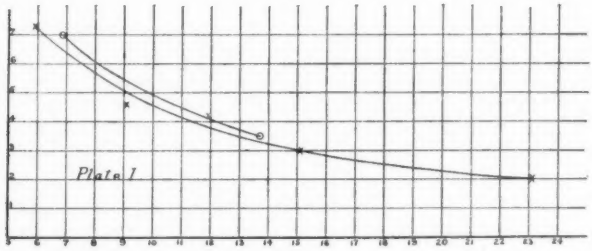
The plan followed was first to measure the resistance of a certain length of the solution on a Kohlrausch bridge. Next, with the solution in series with the spark gap, a photograph of the spark was taken, and the number of half oscillations corresponding to the length in question was plotted against its ohmic resistance. This was done for lengths of the solution of resistance varying from 6 to 24 ohms. The solution was then replaced by manganine wires of different lengths, and the operation repeated. These wires were $0{\cdot}3^{mm}$ in diameter and stretched on both sides of thin vulcanite plates in order to eliminate self-induction. The curves thus obtained were then compared.

The result is shown in the four accompanying figures. Here ohms are plotted horizontally and half-oscillations vertically.

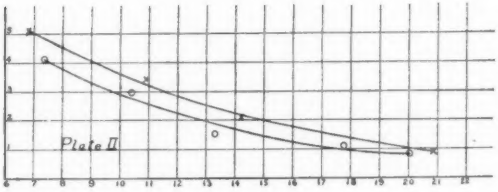
The points on the curves for the wires are indicated by crosses, those on the curves for the solution by circles. Each set of curves was made from a series of continuous observations, since, as may be seen at once by comparing the sets, isolated observations are evidently useless. The observations shown in Plate I were taken May 19, those for Plate II on May 24, and those for Plates III and IV on May 31.

Plates I and II show an apparent inconsistency, the curve for the solution being above that for the wires in Plate I and below it in Plate II. Naturally the curve in Plate I which contains only two points, is less reliable than that in Plate II, which contains six. The fact that in the observations for Plate I the photographs for the wires were all taken first, while in those for Plate II the photographs for the solution were all taken first, may have something to do with this inconsistency. In the case of Plates III and IV the observations were taken thus: first, two photographs for the solution, then two for the wires and so on.

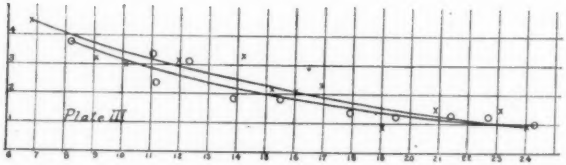
1.



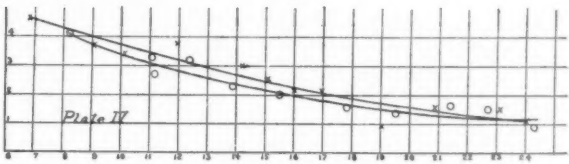
2.



3.



4.



In order to give uniformity to a set of results it was found necessary to scrape carefully the cadmium terminals of the spark gap before taking each photograph. The distance between the terminals was kept constantly at $1{\cdot}5^{mm}$.

The average number of half oscillations of all the isolated sparks on any negative was taken as the representative number. The pilot spark was not counted. The oscillations for Plate III were counted by Mr. Collins, those for the other plates by Mr. Fiske. Plates III and IV were made from the same set of observations.

The free acid in the solution kept the electrodes constantly clean.

The wires themselves show no surface travel. This is indicated by Rayleigh's formula

$$R' = R\left(\pi r \sqrt{\frac{\mu\sigma}{T}}\right) \quad \text{(Phil. Mag. (5) xxi, p. 369, 1886).}$$

or by Stefan's

$$R' = R\left(\pi r \sqrt{\frac{\mu\sigma}{T}} + \tfrac{1}{4}\right) \quad \text{(Wied. Ann., xli, p. 421, 1890).}$$

Here $\mu = 1$; r, the radius, $= {\cdot}0165^{cm}$; σ, the specific conductivity, $= \frac{1}{400000}$; T, the time of oscillation, $= \frac{1}{500000}$ sec. approximately Neither of these formulæ holds because the factor in the parenthesis is in each case less than 1.

That the wires exhibit no surface travel was also shown experimentally. Wires of different sizes and materials but of approximately the same resistance, laid parallel to avoid self-induction, were placed in circuit, the sparks photographed, and the number of half-oscillations compared. The following table gives the result:

No.	Material.	Radius.	Resistance.	No. of half-oscillations.	Remarks.
1	German silver	$0{\cdot}36^{mm}$	8·07 ohms	5	
2	Manganine	0 16	8·07	3·55	Doubtful
3	Iron	0·127	7·75	1·66	"
4	German silver	0·128	8·17	4·73	
5	" "	0·16	8·07	4·8	
6	Like No. 3			1·5	
7	" " 2			5·17	

With the exception of number 2, the negative for which showed only nine sparks, the manganine and German silver wires gave practically the same number of oscillations, namely 5, and we may conclude that there is no surface travel in their case. With the iron wire there is a marked "skin effect," owing doubtless to the large value of μ.

An examination of Plates III and IV, the most reliable results, shows that the points on the solution-curves unquestionably tend to fall below those on the wire curves. The evidence is, then, in favor of a surface travel in the electrolyte.

It is intended to carry this investigation further along the same line, for it seems very likely that, with an apparatus giving a higher period, the existence of a surface travel in electrolytes can be completely established.

Jefferson Physical Laboratory, Harvard University.

Art. XI.—*On Iron Meteorites, as nodular structures in Stony Meteorites;* by H. L. Preston.

[Read before the Rochester Academy of Science, Nov. 9th, 1897.]

It is an important fact that of over one hundred falls and finds of siderites or iron meteorites but nine have been seen to fall, while of the aerolites or stony meteorites of over four hundred falls and finds, some two hundred and sixty, or more than one-half, have been seen to fall.

Does this imply that during earlier centuries, the iron meteorites were more prevalent than at the present time, and *vice versa*, that during the present, the aerolites are more prevalent than during the past? This seems improbable, and the writer will present in this paper some suggestions as to the origin of iron meteorites that have occurred to him while handling many scores of these interesting objects.

In the first place, all the nodular masses of the iron meteorites, known as siderites, are believed to be of the same nature as the small specks, or grains of iron that occur in all the stony meteorites, these nodules being, at one time, surrounded by a magma or ground mass of stony matter, as are the specks of iron in the aerolites.

In all igneous rocks, where there is a concretionary structure, we know that the slower the cooling the larger the concretions; for when in a molten state, solidification commences at certain points. The slower the cooling, the greater amount of material gathered around these nuclei, or points of solidification. The law of molecular attraction—the affinity that an

element has for a like substance, requires time in which to act. As its period of action is of necessity confined to the molten condition of the mass, larger nodules would result during a protracted cooling than where solidification occurs more rapidly. The principle applies to meteorites. The degree of crystallization bears the same relation to time. When rocks become solidified beneath the surface, where the temperature is much higher than that of the atmosphere, the crystalline structure is well defined and marked, due to the slowness of solidification; whereas if solidification takes place after eruption, the crystalline structure is not perceptible, due to rapid solidification.

It is probably true that when iron meteorites enter our atmosphere, they are frequently associated with the stony magma in which they were formed, and the atmospheric resistance causing the mass to explode, would tend to separate this magma along planes of the nodular masses of iron, which, owing to their greater specific gravity, would reach the surface of the earth at a different time and place from their accompanying matrix.

The Estherville meteorite, which fell May 10th, 1879, is a case in point. A number of months after the fall and some four miles distant, were found over five thousand nodules of iron, ranging in size from a pea to a pound in weight. Now these are known positively to be portions of the Estherville meteorite, not only by their resemblance to similar masses found in the meteorite, but from the fact that a number of boys herding cattle near a pond, at the time the meteorite passed over them, saw a great shower of what appeared to be hailstones fall. They state that the surface of the water was alive with the falling bodies.

Therefore, if the larger masses of iron could occur only when the process of solidification was most abnormally slow, we would expect that the majority of meteorites reaching us would be those that contained but small nodules or specks of iron.

It seems probable that certain of the stony meteorites that have been found are really the matrices in which some of the iron nodules, found perhaps many miles distant, were embedded at the moment they entered our atmosphere.

Another distinct and most important point is that the rougher the exterior surface of an iron meteorite, and the deeper and larger its pittings, the more marked is its crystalline structure, and the greater the number and the larger the size of the troilite nodules, as disclosed by slicing and etching. On the contrary, if the exterior surface is comparatively smooth, on slicing and etching, we find the Widmanstätten

figures small, many times imperceptible without a lens, and the troilite nodules small in size and few in number.

In the first case we would infer that the process of solidification was a very slow one, permitting the crystalline structure to be large, and the concretionary nodules of the monosulphide, troilite, to be likewise large.

It is well known that the process of solidification, or crystallization of mineral matter, is a purifying one, and that the tendency is for the purest material in the molten mass to become the first crystallized. In the case of siderites, this would, of course, be the kamacite, and the slower the cooling the greater the amount of impure material cast aside, and the larger the crystals; thus giving the monosulphide a chance to segregate during a longer period of time, causing more numerous and larger troilite nodules than in the second instance where solidification has taken place more rapidly, hence giving less time for the purifying process. In the latter case we would expect a smaller number of the troilite nodules, as well as smaller in size.

It may be asked, why in the coarsely crystalline meteorites should the exterior surfaces be marked by large and deep pittings, while on those in which the crystalline structure is scarcely apparent these pittings should be almost entirely absent. The answer is that when the crystalline structure is coarse, the plates of kamacite are long and broad and the bands of tænite thick. Thus the tendency of separation in the mass would be between the plates of kamacite and the bands of tænite, and in its passage through the atmosphere fissures by the expansion due to heat, caused by friction, would be made along these planes, and cause them to separate, and thus masses would fall out. The rough ragged edges, where the separation took place, would be further fused and worn away until the base of the cavity was again comparatively smooth, causing large and deep pittings.

While in the case where the Widmanstätten figures are small, the blades of kamacite are narrow and short, the bands of tænite thin and there would be a much less chance of separation along these planes, and the degree of fusion over the whole surface would be comparatively the same, which would produce smooth, rounded exterior surfaces, with but few and shallow pittings.

In summary the two following points are affirmed:

First. That siderites have originally been encased in stony matter, and

Second. That the exterior surface of a siderite will give strong indications as to its internal structure.

Rochester, N. Y.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Osmotic Pressure and Electrolytic Dissociation.*—The well-known Van't Hoff theory of osmotic pressure supposes that a substance in solution exercises a pressure equal to that which would be produced if the solvent were entirely removed and the substance left in the state of gas in a volume equal to that originally occupied by the solution. It has been shown by Arrhenius that if P is the osmotic pressure of a solution containing n molecules of a dissolved substance and N molecules of the solvent, d being the density of the solvent, D that of the vapor of the solution and T the absolute temperature, then P is proportional to ndT/ND. If n molecules are contained in unit volume of the solution (or of the solvent if the solution is very dilute) d/M may be substituted for N, where M is the molecular mass of the solvent. If the liquid solvent and its vapor have the same value for M, then at any constant temperature T, this value is a simple constant multiple of D for all solvents. Hence if n is constant, the osmotic pressure is constant, and it follows that n molecules of a dissolved substance in unit volume of any solution have, when the solution is dilute, the same osmotic pressure at constant temperature. Compton has now pointed out that the above assumption, i. e. that the liquid solvent and its vapor have the same molecular mass, is not justifiable. While it is true that many liquids are normal or "monomolecular," the molecules of the liquid being the same as those of its vapor, yet in quite as many other cases, liquids are found to be "associated," their molecules being built up of several gaseous molecules. In this case if M is the normal monomolecular mass, the liquid molecular mass will be xM, the value x being the factor of association, and representing the number of normal molecules going to form one molecule of the associated liquid; n normal molecules forming n/x liquid molecules. Hence the question arises, if association takes place in either solvent or dissolved substance, what effect will be produced on the osmotic pressure? Evidently this will be no longer constant but will vary proportionally to x. Now the hydrocarbons and their halogen derivatives, the ethers, most etherial salts, most aldehydes and ketones and probably the acid anhydrides, may be considered monomolecular; while the alcohols and allied compounds, the organic acids, the oximes, some nitro-compounds, and compounds containing amidogen, may be viewed as associated. In place of using the osmotic pressure itself to test the question, certain relations between this value and certain other properties of solutions were used for the purpose. Thus, if r be the heat of liquefaction of a solvent whose density is d and absolute fusing point T, then for a monomolecular liquid having a normal vapor density, the value rd/T is con-

stant; while if the liquid be not monomolecular this constant must be multiplied by x/a where x is the factor of association of the liquid and a that of the vapor. From tabular results of r, d and T given in the paper, the value rd/T is calculated; and it appears that while the mean value for monomolecular liquids is practically constant at about 0·099, that for associated compounds, while consistent with the theory, is considerably greater, that for water being about 3 and acetic acid 2·71. Similar results are obtained from a study of the lowering of the freezing point. While monomolecular compounds in monomolecular solvents agree well with Van't Hoff's theory, associated compounds in monomolecular solvents, monomolecular compounds in associated solvents and associated compounds in associated solvents, differ from it considerably; though in the last case the values equal those required by the corrected theory when x/a equals x_1. Hitherto the deviations from Van't Hoff's theory of osmotic pressure obtained by the cryoscopic method have been explained by the hypothesis of electrolytic dissociation. But the above results clearly show that this hypothesis is entirely unnecessary for this purpose. No account has been taken of association in the liquid state, either for the solvent or the dissolved substance, and it is this which has necessitated the introduction by Van't Hoff of the now celebrated coefficient i for aqueous solutions upon which the hypothesis of electrolytic dissociation was founded. The author concludes as follows: "(1) Van't Hoff's law of osmotic pressure does not hold in its original form when either the solvent or the dissolved compound are associated. (2) The latent heat of fusion, melting point on the absolute scale, and density at the melting point, of a liquid, are connected by the expression $rd/T=$const. for monomolecular liquids, or $rda/Tx=$const. for associated liquids, the value of the constant being 0·099 or roughly 0·1. (3) The molecular reduction of the freezing point for monomolecular compounds in monomolecular solvents is given by Van't Hoff's formula $E=0{\cdot}01976T^2/r$ or by the derived formula $E=0{\cdot}2Td$. If, however, the dissolved substance or the solvent are associated, this formula no longer applies, but $E=0{\cdot}01976T^2x/rax_1$ or $E=0{\cdot}2\ Td/x_1$. (4) Exceptions to Van't Hoff's formula for the molecular reduction of the freezing point, appear therefore whenever association of either dissolved substance or solvent takes place, and the hypothesis of electrolytic dissociation is not only unnecessary in explanation of these exceptions but inconsistent with what is now known of the nature of liquids. (5) Electrolytes are salts in an approximately monomolecular fluid state, in solution in associated solvents."—*J. Chem. Soc.*, lxxi, 925–946, August, 1897. G. F. B.

2. *On the Electrolytic Decomposition of Aqueous Solutions.*—A lecture has recently been given by Nernst before the German Chemical Society in which he considers the chemical mechanism of the electrolytic decomposition of aqueous solutions. He showed in 1889 that the potential difference between a metal and

a solution may be calculated from the solution pressure of the metal and the osmotic pressure of the solution; and hence it follows that the electromotive force of a galvanic cell formed by combination of two different electrodes is easily obtained. Conversely, Le Blanc in 1891 determined the minimum electromotive force required to produce sensible electrolysis in a given solution. Since theory and practice were somewhat discordant, Le Blanc considered that in some cases water might act as a primary electrolyte and suffer direct decomposition by the current. According to his measurements 1·68 volts are necessary to do this; while Smale working under Ostwald's direction gives 1·08 volts as the maximum. Investigations made by Glaser in the author's laboratory show that in the case of sulphuric acid and potassium hydroxide solutions, a primary decomposition of water can be effected with an electromotive force of 1·08 volts, provided the positive platinized electrode on which the oxygen separates be large enough. The value 1·68 volts characterizes further decomposition in these solutions. Nernst suggests that possibly there may be dissociation of the water not only into the ions OH and H, but also into H, H and O, and that the latter ions correspond to the lower electromotive force, while the hydroxyl and hydrogen ions are set free by the higher one. An interesting table is given showing the voltage necessary to separate certain kations and anions from solutions of normal concentration. These are: Ag −0·78; Cu −0·34; H 0·0; Pb+0·17; Cd+0·38; Zn+0·74 for kations; and I 0·52; Br 0·94; O 1·08; Cl 1·31; OH 1·68; SO_4 1·9; HSO_4 2·6 for anions. To calculate the electromotive force, for example, required to electrolyze a normal solution of zinc bromide we have 0·94+0·74=1·68 volts; while to decompose hydrogen chloride there is needed 1·31+0=1·31 volts. Moreover from the above values a conclusion can be reached as to the possibility of separating certain ions electrolytically. Electromotive force, however, is only a single factor in these changes; the other factor, ionic concentration, must also be taken into the account.—*Ber. Berl. Chem. Ges.*, xxx, 1547–1563, July, 1897.

G. F. B.

3. *On the Direct production of Iron Carbide.*—As a crystalline carbide of iron Fe_3C has been shown by several observers to exist in fused or annealed steel, Moissan has investigated the direct action of carbon on iron in the electric furnace. When pure iron is heated with charcoal from sugar in this way, the mass becomes more and more viscous as the temperature rises, resuming its fluidity as it cools. But only about one per cent of carbon in combination was found in the cold metal. If therefore carbon and iron unite at a high temperature, dissociation must result as the mass cools. The same is true of nickel. In preparing diamonds it had been noticed that the interior of the iron contained brilliant crystals resembling iron boride or silicide. The conditions necessary to ensure combination, apparently, are to avoid saturating completely the iron with carbon, and to pre-

vent the formation of graphite. Hence Swedish iron was heated in a carbon crucible for three minutes by means of an arc given by 900 amperes and 600 volts, and the fused mass poured into water. A very hard, brittle metal resulted, frequently highly crystalline, containing 3 or 4 per cent of combined carbon but very little graphite. To isolate any carbide present, the author used (*a*) an electrolytic method and (*b*) the action of very dilute acids, out of contact with air. Normal nitric acid gives a carbide mixed with carbon, but a half normal acid gives practically pure carbide. After separating adhering impurities, iron carbide is obtained in the form of brilliant white crystals having the composition Fe_3C and a specific gravity of 7·07 at 16°. It is apparently identical with the carbide present in steel and is not affected by oxygen at the ordinary temperature, though it is acted on by moist air containing carbon dioxide. In the state of very fine division it ignites in the air below 150°. It becomes incandescent in vapor of sulphur at 500°, in chlorine below 100°, in bromine vapor at about 100°, and is decomposed by iodine at a red heat. Hydrogen chloride decomposes it at 600° with evolution of hydrogen containing traces of hydrocarbons; but heated in a sealed tube, the products of the reaction are hydrogen and methane. Neither water nor solutions of sodium or magnesium chloride have any action on the carbide at 150°.—*C. R.*, cxxiv, 716–722, April, 1897. G. F. B.

4. *On the Production of Peroxides in Slow Oxidation.*—In order to test the question whether slow oxidation is always accompanied by the formation of peroxides, Bach has made numerous experiments, the results showing that nascent hydrogen, phosphorus, sodium, potassium, zinc, iron, lead, methyl alcohol, ethyl alcohol, isopropyl alcohol, glycerin, formaldehyde, acetaldehyde, benzaldehyde, glucose, acetic, oxalic and tartaric acids, ethyl ether, acetic anhydride, phenol, resorcinol, catechol, tannin, pyrogallol, dimethylaniline, diethylaniline, phenylhydrazine, formamide, acetamide, terebenthene, benzene, petroleum, quinine sulphate, morphine acetate, brucine and strychnine all give peroxides on slow oxidation in the air either in the light or in the dark. Since these compounds belong to very varied groups and since the oxidation involves the splitting up of the oxygen molecule O : O, it is reasonable to suppose that in the earlier stages of the oxidation, the substances combine with the grouping ·O·O· to form peroxides, the splitting up of O : O into ·O·O· requiring less energy than into ·O· and ·O·. Peroxides are also produced by energetic oxidation, and they may be detected in water on which a flame of hydrogen or carbon monoxide is allowed to play; percarbonic acid being formed in the latter case. Moreover these peroxides, when formed, facilitate further oxidation. When air is passed through a solution of indigo mixed with terebenthene or benzaldehyde the indigo is rapidly oxidized to isatin. Nascent hydrogen liberated from palladium produces a similar effect when oxidized by air, and in this case the indigo is com-

pletely oxidized when the quantity of active oxygen in the liquid is considerably less than that in the hydrogen peroxide that suffices to oxidize the indigo under ordinary conditions. The author regards these results as showing (1) that Hoppe Seyler's view that the nascent hydrogen splits up the ordinary oxygen into one atom with which it combines and another which is set free and is capable of producing energetic oxidations, is not tenable; and (2) that the intermediate product is probably not hydrogen dioxide but hydrogen tetroxide. In the blood the readily oxidizable substances first form peroxides and these oxidize the less readily oxidizable substances, in the same way that the peroxide formed by the terebenthene oxidizes the indigo. The so-called oxidizing ferments in the blood are simply readily oxidizable substances having a special aptitude for forming peroxides.—*C. R.*, cxxiv, 951–954; *J. Chem. Soc.*, lxxii, 401, Sept., 1897. G. F. B.

5. *On the Constitution of Phosphorous acid.*—It has been difficult to decide between the two formulas for phosphorous acid $P(OH)_3$ and $PHO(OH)_2$, since all the various reactions can be interpreted by either of them. Michaelis and Becker have now obtained evidence of the existence of the latter form. On treating lead phosphite $PbHPO_3$ with ethyl iodide at 175° it yields diethyl phosphite $PHO(OEt)_2$; the same substance which Thorpe and North obtained by acting on alcohol with phosphoric oxide. This compound when treated in ethereal solution with sodium and then with ethyl iodide, yields diethyl ethylphosphinite $PEtO(OEt)_2$, which is isomeric with ethyl phosphite $P(OEt)_3$, though it differs from it in all its properties. Thus it boils at 198°, has a specific gravity of 1·025 at 21° and does not reduce mercuric chloride or precipitate magnesium mixture; while ethyl phosphite boils at 191°, has a specific gravity of 1·075 and reduces mercuric chloride. Diethyl ethylphosphinite is also formed when ethyloxychlorophosphine $PEtOCl_2$ is treated with sodium ethoxide. Ethylphosphinous acid stands to phosphorous acid, therefore, in the same relation as ethylsulphonic acid to sulphurous acid.—*Ber. Berl. Chem. Ges.*, xxx, 1003–1009, May, 1897. G. F. B.

6. *On the Manufacture of Ammonium Cyanide.*—It has been shown by Lance that when ammonia is passed slowly over wood charcoal heated to 1000°–1100° ammonium cyanide is always formed. The yield of cyanide is a maximum at this temperature and twenty-five per cent of the nitrogen in the ammonia is converted into cyanogen. This yield, however, is greatly increased if the ammonia be mixed with nitrogen and hydrogen, especially when the latter is in excess. Indeed the yield of cyanogen may be nearly 90 per cent of the ammonia when 200^{cc} of ammonia is mixed with 5000^{cc} of hydrogen and 500^{cc} of nitrogen. Under these latter conditions at least 70 per cent of the nitrogen in the ammonium cyanide is derived from the free nitrogen in the gaseous mixture.—*C. R.*, cxxiv, 819–821, April, 1897.

G. F. B.

7. *Jahresbericht über die Fortschritte der Chemie und verwandter Theile anderer Wissenschaften.*—Begründet von J. Liebig und H. Kopp. Herausgegeben von F. Fittica. 1891, Viertes Heft, November, 1897; 1896, Erstes Heft. Braunschweig (Friedrich Vieweg & Sohn).—The fourth number for 1891 of this most valuable publication has recently been issued; it contains pages 1441–1920, with table of contents. With this has appeared also the first number for 1896, pages 1–324.

8. *The change of alternating currents into direct.*—This has been accomplished by various mechanical devices, and by employing an alternating current motor to run a direct current dynamo. L. GRAETZ calls attention to a very interesting method of accomplishing this purpose, which depends upon a remarkable property of aluminium. It has long been known that in an electrolytic cell in which one of the electrodes is of aluminum, a remarkable weakening of the current sent through the cell is produced if the aluminum constitutes the anode and if it is in the presence of oxygen, while no weakening of the current results if the aluminum is made the cathode. This phenomenon is variously explained. By some it is supposed to be due to a layer of badly-conducting oxide on the anode, by others to a resistance developed during the passage of the current, by others to a species of condenser working between the electrode and the fluid, and to a kind of dielectric polarization, which is not the common electrolytic polarization. The reason of this last hypothesis is based upon the fact that currents of less electromotive force than 22 volts cannot flow through the cell, and currents of higher electromotive force have their tension reduced to this amount.

The fact that after stopping the current no residual polarization, approximating to the value of the apparent polarization, can be found, is opposed to the idea of electrolytic polarization. A dielectric condenser effect, however, would explain this fact. The other electrode in the cell plays no important part. It can be made out of platinum or other metal. The author uses carbon, and any liquid which will develop oxygen on the electrode: he has especially employed alum solutions. If an alternating current is sent through a series of such cells, and if the number is sufficiently great, so that the anode polarization exceeds or at least is equal to the electromotive force of the alternating current, the positive portion of the current would be stopped by the cells and only the negative portions would pass through. The cells thus separate the positive currents from the negative, and by means of a simple arrangement of the cells an alternating current can be changed into a direct. Under certain conditions as much as 95 to 96 per cent of the energy of the alternating current can be changed into the energy of direct currents.— *Wied. Ann.*, No. 10, 1897, pp. 322–327. J. T.

9. *Observation of air waves.*—Helmholtz has shown, that if a warmer and lighter layer of air moves over an under layer of

colder and heavier air, the same conditions arise as in the case of the wind blowing over a surface of water. Waves are formed on the surface of the under layer of air, which are perpendicular in direction to the wind and which follow each other at regular distances. These air waves can have very great dimensions. The same wind which would produce waves on water a meter long, could produce in layers of air which differ in temperature 10°, waves two to five kilometers in length. Sea waves five to ten meters in length would be represented by air waves fifteen to thirty kilometers in length. R. EMDEN describes a journey in a balloon from Munich—in November, 1896—and in the course of it he saw below him stretched over Munich great layers of clouds. which looked like giant sausages. Fifteen of these rolls or layers were counted, and they ran at right angles to the direction of the wind. The author discusses Helmholtz's paper, "On Atmospheric Movements" (Gesammette Abhandlungen, iii, p. 309), and believes that the phenomenon he witnessed is exactly such as would result from Helmholtz's theoretical deductions. — *Wied. Ann.*, No. 10, 1897, pp. 374–378. J. T.

10. *Light, visible and invisible:* A series of lectures delivered at the Royal Institution of Great Britain at Christmas, 1896; by SILVANUS P. THOMPSON. 294 pp. New York and London, 1897 (The Macmillan Company).—The special conditions under which the lectures here presented to the general public were delivered has determined the form and method of this volume by Professor Thompson. The general reader is the gainer, because of the simplicity and directness of the style adopted and the liberality in the introduction of illustrations. The volume occupies a somewhat new field, since it not only reviews the phenomena of light in the narrow sense, with a discussion of the invisible spectrum, but treats also of the long electric waves discovered by Hertz and further of the discoveries of Röntgen. An interesting chapter is devoted to the work of Hertz and his followers and an appendix follows on the electrical theory of light. The last lecture is devoted to the production and phenomena of the X-rays of Röntgen, which the author ventures to call "Röntgen light." This subject is clearly presented with numerous illustrations of a familiar kind. The appendix contains a summary of other kinds of "invisible light."

In the strictly optical part of the work the author develops the subjects of reflection, refraction, etc. from the wave theory, and in the appendix following shows how the essential formulas for lenses can be deduced by this method (see Phil. Mag., Oct., 1889).

11. *Bibliography of X-ray Literature and Research* (1896–1897). Being a ready reference index to the literature on the subject of Röntgen or X-rays. Edited by CHARLES E. S. PHILLIPS. With an Historical Retrospect and a chapter, "Practical Hints," by the editor. Pp. xxxii and 68. New York, 1897. (The Electrician Company, London; D. Van Nostrand, New York.)—The literature of the X-rays has increased so rapidly since the publication

of Röntgen's paper, nearly two years since, that it is impossible for many of those now interested in the subject to keep themselves fully informed as to what other workers have done. Hence this carefully prepared and conveniently arranged bibliography will be found widely useful. It is intended to include references to all important papers that have appeared up to March, 1897. The editor has given in the introduction a brief summary of the historical development of the subject; he also adds a chapter giving suggestions as to the best method of overcoming some of the mechanical difficulties involved.

12. *Tafeln und Tabellen zur Darstellung der Ergebnisse Spectroskopischer und Spectrophotometrischer Beobachtungen.* Herausgegeben von Th. W. Engelmann, Professor in Utrecht. Leipzig, 1897 (Wm. Engelmann).— This publication includes ten copies of each of two accurate and well executed plates and two sets of tables. The first of the plates gives at the top the solar spectrum with the Fraunhofer lines and in line with this below five copies of the spectrum of white light with scale divisions arranged according to wave length (from 80 to 40). This plate is designed as a foundation to be used in recording the various absorption spectra under examination. The second plate gives at the top the usual colored spectrum with a similar scale, the position of the Fraunhofer lines are also indicated; below are a system of ruled horizontal lines, the vertical lines corresponding to the wave lengths and the horizontal lines arranged from 100 to 0. This plate is intended for use in the photometric measurements connected with the observations of absorption spectra; detailed suggestions are added in regard to the proper method of recording to be employed.

Of the two tables, the first gives the numerical values of the coefficients of extinction (e) for variations of light intensity (i) from 99·5 to 0·1. The second gives the relative intensities of the light transmitted through layers of thicknesses 1·0 to 0·1, relating to the amount of coloring material present.

II. Geology and Natural History.

1. *Paleozoic faunas of the Argentine;* Professor E. Kayser of Marburg, in an article entitled "Beiträge zur Kenntniss einiger palaeozoischer Faunen süd-Amerikas," (Zeitschr. d. deutsch. Geol. Ges., 1897,) has brought together a valuable description of the paleontological faunas of Argentine accessible to study in Germany. Five separate lots of fossils from different sources and collected by different hands were studied and results reached. These may be summarized as follows:

I. A Cambrian fauna from Iruya and Ojo de Agua in the province of Salta, Northern Argentina, in a grey, fine-grained quartzite sandstone, contains the following species, viz: *Liostracus Steinmanni* n. sp., *L. Ulrichi* n. sp., *Agnostus iruyensis* n. sp., *Orthis saltensis* Kays. ?, *Lingulella* cf. *ferruginea* Salt., and *Lingulella* cf. *Davisii* Salt.

II. A Lower Silurian (Ordovician) fauna came from Portezuelo near Salta, in the province of the same name, and from Mudana in the province of Jujuy. The first was in a firm yellow quartz sandstone; and the second from a fine-grained, micaceous, somewhat slaty, yellowish grey sandstone. The fossils noted are *Megalaspis* sp., *Bellerophon* sp. and *Didymograptus* sp.

III. Another Lower Silurian fauna was obtained from a limestone in Cerro del Fuerte, east from Jachal in the province of San Juan. This fauna contains the species *Illaenus Argentinus* n. sp., *Maclurea Avellanedæ* Kays., *Leptæna sericea* Sow., and *Orthis calligramma* Dalm. ?

IV. The Devonian fauna occurs at several horizons in a series of rocks lying apparently comformably upon the Lower Silurian limestones, in the neighborhood of Jachal. The chief locality is at Cerro del Fuerte, east of the Jachal River. The rocks are described by Bodenbender as about 400 meters thick. The lower 200 m. consists of barren clay slates. In the upper 200 m. of slates and grauwacke there are three fossiliferous horizons. The lower zone contains *Leiorhynchus Bodenbenderi* and *Leptocœlia acutiplicata*; the middle zone contains besides the same *Leptocœlia*, also, *Chonetes fuertensis*, *Phacops*, *Homalonotus*, *Tentaculites*, *Bellerophon*, etc.; the upper zone contains *Spirifer antarcticus* (=*chuquisaca*), *Chonetes folklandica*, *Vitulina pustulosa* and several bivalves.

The second locality is west of the Jachal River, at Cerro del Aqua Negra and at Cerro Blanco. The formation here is 2000–3000 m. thick, and is composed of grauwache, sandstones, quartzites, slates and very subordinate beds of limestones. At the Cerro del Aqua Negra locality only the first fauna appears with *Leior. Bodenbenderi*, *Leptoc. acutiplicata* and *Tropidoleptus fascifer*. At Cerro Blanco two higher faunas appear, the lower marked by numerous remains of *Lingula subalveata* and *Pholadella radiata*, and the upper by numerous conularia, starfish, crinoids, *Spirophyton*, etc.

The list of species of the Devonian fauna is as fellows, viz: *Cryphæus* sp., *Phacops* cf. *rana* Green, *Homalonotus* sp., *Orthoceras* sp., *Naticopsis?* sp., *Bellerophon* sp., *Bellerophon* aff. *Murchisoni* d'Orb., *Conularia Quichua* A. Ulrich ?, *Tentaculites* sp., *Leptodomus* sp., *Pholadella radiata* Hall., *Allerisma?* sp., *Tropidoleptus fascifer* n. sp., *Liorhynchus Bodenbenderi* n. sp., *Liorhynchus? Brachebuschi* n. sp., *Meristella?* sp., *Leptocoelia acutiplicata* Conr., *Vitulina pustulosa* Conr., *Spirifer antarcticus* Morr. et Sharpe, *Orthothetes* sp., *Orthothetes* cf. *arctostriatus* Hall, *Chonetes folklandica* Morr. et Sharpe ?, *Chonetes fuertensis* n. sp., *Chonostrophia* sp., *Lingula* (*Dignomia*) *subalveata* n. sp., *Orbiculoidea* cf. *humilis* Hall.

V. A few fossils of Devonian age are described from Coloolo and Chililaya, two points near the shores of the Titicaca sea. The rock in the first case is a hard blackish slate, the second is a yellowish, fine, sandy clay rock. The fossils reported are *Homa-*

lonotus sp. (recalling to the author most nearly *H. Herscheli* Murch. from Capland described by Salter), *Leptocœlia flabellites* Conr. and *Retzia?* sp.

The study of the above faunas has led the author to make the following correlations:—The Iruya fauna he refers to the Middle Cambrian, or Paradoxides zone of the Swedish section, and he has revised his correlation of Cambrian fossils, previously* described from the Argentine Republic, referring them now, also, to the Paradoxides zone instead of to the Upper Cambrian according to his first conclusion.

The Lower Silurian fauna (2 and 3) is correlated with the north European "Orthocerankalk."

No trace of the Silurian (Ober-silur) has been discovered in the region, and the author quotes Prof. Bodenbender as reporting the Devonian as lying, by transgression, immediately upon the Lower Silurian limestone in the neighborhood of Jachal. The Devonian faunas (4 and 5) are found to represent more closely the faunas of the Hamilton and Upper Helderberg formations of New York than any other faunas of the northern hemisphere.

A review of the various known Devonian faunas of South America has led the author to the conclusion, that several faunas very closely related to each other extend over an immense extent of surface of that region of the earth. Also that the Devonian fauna of Capland is intimately associated with them. These faunas correspond closely to those of the Upper Helderberg and Hamilton formations of North America. All belong alike with them either to the younger Eodevonian or to the older Mesodevonian age, while the older Eodevonian and the younger Mesodevonian and the Neodevonian are not represented, paleontologically, at any point in the whole region, so far as at present known.

The fossils referred to in this interesting report were collected by Professors Bodenbender and Brackenbusch, and Drs. Berg, Valentin and Hettner. H. S. W.

2. *Volcanoes of North America; a reading lesson for students of geography and geology;* by ISRAEL C. RUSSELL, pp. 1–346, plates 1–16, figures 1–71. 1897. (The Macmillan Co.)—Professor Russell introduces the general reader for the first time to a particular knowledge of the volcanoes of the North American continent, and to the peculiar phenomena and physical features traced directly to volcanic action. In the first chapter (pp. 1–126), the characteristics of volcanoes are explained by reference to those of sundry types found in all parts of the world. The selection of these examples is wisely chosen, because of the fuller knowledge we possess of volcanoes situated in the midst of the older civilized countries than of the American volcanoes, equally good as illustrations, but the very existence of many of which has been learned within the last half century. A brief chapter on the

* Kayser: Ueber primordiale u. untersil. Foss. aus der Argentinischen Republik. Palaeontographica, Suppl. 1878.

general distribution of volcanoes follows, and then in the third, fourth and fifth chapters descriptions are given of the several volcanoes, in the order of their distribution, found in Central America, Mexico and along the Cordilleran region of the United States to its most northern province Alaska, and in the Aleutian belt of islands, where the greater number are of volcanic origin. In these descriptions typical examples of volcanic mountains and of lava flows are selected for presentation, and they make a series of the author's characteristic portraits of nature, the more truly artistic and impressive because of their severely accurate and realistic nature. We are made to see these from the point of view of a scientific observer who has done not a little, himself, to explore and bring to light the American wonders of both fire and ice.

The theory of volcanoes is left for the seventh chapter, after the reader has learned what volcanoes are, and it is not till the facts and theories are both before us that the author gives free leash to the imagination and vividly depicts the life history of a volcanic mountain. The book is thoroughly readable and instructive, and the reader is referred all along the way to the original literature where fuller scientific elaboration of the facts may be found. H. S. W.

3. *British Museum Catalogues:* (Catalogue of Tertiary Mollusca in the Department of Geology, British Museum of Natural History. Part I. The Australasian Tertiary Mollusca; by GEORGE F. HARRIS, pp. i–xxvi, 1–407, plates I–VIII. London, 1897.) Catalogue of the fossil Cephalopoda. Part III, containing the Bactritidæ and part of the suborder Ammonoidea, by ARTHUR H. FOORD and GEORGE C. CRICK, pp. i–xxxiv, 1–303, figures in the text 1–145. London, 1897.

The two new numbers of the increasingly valuable series of British Museum Catalogues, whose titles are here given, have been recently received.

Mr. Harris, in the Catalogue of Australasian Tertiary Mollusca, has done a particular service to paleontology in bringing to notice the phylogenetic characters of the Gasteropoda, and in using the characters expressed in ontogenetic development of individuals for the close discrimination of the geological age of the faunas to which they belong. The plates contain a large number of illustrations of the protoconchs of Gasteropoda, beautifully drawn by Miss G. M. Woodward.

The Catalogue of the Cephalopoda is augmented by a volume on the Goniatites. The authors have brought the classification and nomenclature of Goniatites up to date, given a brief synopsis of the chief steps in the historical modifications in nomenclature. The figures are particularly valuable in bringing together representations of the suture lines for a large number of the species described. H. S. W.

4. *Coral Boring at Funafuti.*—It is stated in *Nature* of Dec. 9, that the coral boring carried on in the atoll of Funafuti under

the supervision of Prof. David has reached a depth of 643 feet. In regard to the deposits passed through, three zones have been recognized. The *first* extended to a depth of 200 feet; of this 40 feet were made up of coral reef rock and below the material was also largely derived from corals with brief interludes of true reef. The *second* zone, from 200 to 373 feet, consisted largely of sandy material, sometimes a calcareous mud, with occasional coral fragments. These deposits are not reef but were doubtless formed in the neighborhood of a reef. The *third*, or lowest, zone corresponds apparently to the first; the character of the material suggested that it was formed near a reef which occasionally extended out laterally, building up layers of true reef upon detrital coral. Much of the rock pierced at this depth was a hard and compact coral limestone.

Prof. David, though not attempting as yet to discuss the theoretical bearing of the facts obtained, remarks that they prove that true reef has been pierced to a depth of more than 600 feet. Further, for the whole time represented coral must have been growing in great abundance in some part of the locality now represented by Funafuti, the atoll being completely isolated from all other coraliferous localities.

5. *Origin of the Diamonds of South Africa.*—In an article in recent numbers of the *Geological Magazine*, describing some rock specimens from Kimberley, South Africa, T. G. Bonney presents his conclusions in regard to the origin of the diamonds and the volcanic phenomena of the region as follows:

I believe, as I have already stated, that the diamonds were not produced where they are now discovered, but, like the conspicuous olivine, pyroxenes, mica, garnets, and iron-oxides, had their origin at a much greater depth in the earth's crust. Thus I think it improbable that the carbon was obtained from the Karoo Shales. In other words, I consider the diamonds, whatever may have been their past history, to have come from the crystalline floor on which these shales were deposited, or to be at any rate Pre Triassic in age. I see no reason why carbon should not be present in the earth's magma, whether it afterwards crystallized in a peridotite or in native iron.

Volcanic action probably began before the end of the Karoo epoch, as the great sheet of so-called melaphyre seems to be intercalated with its higher deposits, and some of the dykes may be approximately coeval with it. Afterwards (was it because of this impenetrable cover of lava?) the pipes were formed, probably in a short time, by a series of great explosions, caused by gases accumulated at considerable depth. These sent the outer part of the crystalline floor, including the diamonds, as well as the overlying Karoo shales, flying shattered into the air. Cones and craters may have been built up above these pipes, but I expect that, like some of those in the Eifel, they were never high, and that the shattered material mostly fell back, after a few explosions, into the pipes and filled them like the "necks" in Scotland.

Then the volcano, after some more lava had struggled to reach the surface (forming, at any rate, the dykes in the necks), passed into a solfatara stage, during which the numerous secondary changes mentioned above were produced, the carbonates were deposited, and the minor structure of the mass was obscured. Afterwards ordinary meteoric agencies began to work; water percolating from above still further affected the mass, more especially in its upper parts, producing the "yellow ground" and the "soft blue" and depositing tufa.

The result of this examination is to confirm me in my opinion that the diamantiferous rock—the so-called Kimberlite—is a volcanic breccia rather than a peculiar form of peridotite. While it is difficult, owing to secondary changes, to demonstrate the fragmental character of the matrix, I have failed to identify it with any form of peridotite (or serpentine) known to me, and I cannot understand how masses of that rock, the smallest of which is about 370 yards in diameter, masses of which one has been traced to a depth of 500 yards, could remain throughout in a practically uniform glassy condition.

6. *Les Diamants du Cap;* par L. De Launay. 226 pp., with many illustrations. Paris, 1897 (Baudry et Cie.)—The subject of the diamond production of South Africa is one which never fails to be of interest, and this recent contribution to it by Professor L. De Launay deserves the attention it will have from many readers. The author is well-known from his earlier volumes, the first an exhaustive treatise on mineral veins in general (this Journal, vol. xlvi, 309, 1893), and the second on the gold mines of the Transvaal (ibid., ii, 88, 1896).

The present volume does not attempt to be a complete treatment on the diamond—such an one, for example, as was published some years ago by M. Boutan,—but is limited to the occurrence in South Africa with only a brief allusion to other regions. A recent visit to Africa has given the author opportunity to make original observations for himself. An account is given of the early discoveries here in 1867, and the gradual development of the industry from the time when a multitude of individual claims were worked at the various localities to the present condition of affairs, where the whole output is practically controlled by one syndicate. It is interesting to note that according to the table given by the author, the African mines in Griqualand have yielded since 1867 about 12,000,000 kilograms of diamonds, valued at $360,000,000; this does not include the production of the Jagersfontein mine in the Orange Free State. A figure is given of the largest diamond which has been found—the Excelsior diamond of Jagersfontein; this is a mass of a rather irregular triangular form, three inches in its longest dimension and weighed as found 971 carats.

An interesting account is given of the geology of the deposits, with numerous illustrations, and then the author goes on to discuss the method of exploitation and the treatment of the various materials brought up in the mining. In regard to the method of

formation of diamonds in general, the author refers to the interesting and remarkably successful synthetic experiments by M. Moissan and concludes that the conditions of formation in South Africa must have been very similar.

7. *The Building Materials of Pennsylvania. I. Brownstones;* by THOMAS C. HOPKINS. 122 pp. Appendix to the Annual Report of Pennsylvania State College for 1896.—This is an interesting account of the Mesozoic brown and red sandstones used as building material in Pennsylvania. It discusses their general features with respect to chemical and mineral composition, microscopic structure, behavior under physical tests, and similar points, and further gives detailed descriptions of the various portions of the brownstone area in which quarries have been located. A brief summary of the brownstones from other localities in the United States closes the work. Some twenty-six full-page plates give illustrations of the quarries, prominent buildings and bridges in which the material has been used, and other points.

8. *A Catalogue of Minerals, alphabetically arranged, with their Chemical Composition and Synonyms;* by ALBERT H. CHESTER. Third edition; 56 pp. 8vo. New York and London, 1897 (John Wiley & Sons).—We have here an alphabetical list of mineral names now in use, including names of species, their synonyms, and prominent varieties. With the first is given a brief statement of the chemical composition. Collectors will find this useful as a check list.

9. *Synopsis Mineralogica; Systematische Uebersicht des Mineral-reiches;* by Dr. ALBIN WEISBACH. Dritte Auflage. 97 pp. Freiberg, 1897 (J. G. Engelhardt).—After an interval of thirteen years, Prof. Weisbach has given us a new third edition of his "Synopsis of Mineral Species." Its scope is too well known to require any special explanation. The many who have found it useful in the past will be glad to have it thus brought fully up to date.

10. *Eighth Annual Report of the Missouri Botanical Garden.* —Professor TRELEASE incorporates with his specific report as Director, three papers of high value. The report itself possesses much interest as indicating the great scientific activity of the establishment under charge of the director, and showing how symmetrically the work in different lines is being developed.

M. J. Cardot contributes a memoir entitled, *The Mosses of the Azores*, and a second paper, *On some mosses collected in Madeira by William Trelease, in June, 1896.* Professor Trelease presents a memoir, *Botanical Observations on the Azores*, in which he gives the results of his studies in these islands, during part of 1894 and 1896. It is needless to speak of this valuable communication in detail, but attention must be called to the thoroughness of the treatment, and the excellence of the illustrations.

The volume concludes with a list of the publications of the Garden, and of those issued by the instructors in the Shaw School of Botany, attached to it. G. L. G.

11. *Catalogus Mammalium tam viventium quam fossilium*, a Doctore E. L. TROUESSART, Parisiis. Nova Editio (Prima completa). Fasciculus III. 664 pp., Berlin, 1897 (R. Friedländer & Sohn).

The last published part of this valuable work embraces pp. 453–664, and includes the Myomorpha, Hystrichomorpha, Lagomorpha of the Rodentia, II.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Institute of France, Cuvier Prize.*—At the session of the *Académie des Sciences* held at Paris, December 13, 1897, the Cuvier Prize of 1,500 francs was awarded to Professor O. C. Marsh, of Yale University. This prize is "awarded every three years for the most remarkable work either on the Animal Kingdom or on Geology."

2. *Mazama: A Record of Mountaineering in the Pacific Northwest. Crater Lake number*, vol. i, No. 2, 298 pp. Portland, Oregon, 1897. (Published by the Mazamas.)—The society, named the Mazamas, has as its main object the exploration of the snow peaks and other mountains of the Pacific Northwest, and the collection and dissemination of scientific knowledge in regard to this region. The first number of their publications was issued in May, 1896, and contained some twenty-two articles chiefly relating to the snow peaks, Mount Hood and Mount Adams. The second number, recently issued, is given to Crater Lake. It presents to the reader a series of articles by different writers, describing the scenic features of the lake, its discovery and early history, its geology, fauna and flora. A large amount of interesting and valuable information is thus brought together in regard to this remarkable spot. The numerous excellent plates which accompany the number give an excellent impression of the beauty of the scenery. It will be remembered that an article on the Geology of Crater Lake was published in this Journal for March, 1896, by Mr. J. S. Diller.

3. *Kleinasiens Naturschätze*, seine wichtigsten Tiere, Kulturpflanzen und Mineralschätze, vom wirtschaftlichen und kulturgeschichtlichen Standpunkt von KARL KANNENBERG. Mit Beiträgen von Prem.-Lieut. Schäffer. Mit xxxi, Vollbildern und II Plänen, pp. 274. Berlin, 1897. (Gebrüder Borntraeger.)—This is a concise and interesting summary of the prominent animals, the plants and trees, also the mineral resources of Asia Minor. To each section is added a summary of the literature of the subject and also a list of the Turkish and local names for the different objects.

The book is profusely illustrated by half-tone reproductions of photographs, which give a very satisfactory impression of the natural features and life of the region. Of the plates, two the most noteworthy are those showing the basaltic columns of Kurû Seráï near Boyabád, which are remarkable for their height and regularity.

4. *Applied Mechanics*; by JOHN PERRY, F.R.S., pp 678, with 371 illustrations and 25 tables. London, 1897 (Cassell & Co.).—This book embodies the course of instruction in Applied Mechanics at the Finsbury Technical College, which is based on the laboratory method, each student being furnished with tools for measuring the quantities used in every discussion. It is described in the title as "a treatise for those students who have time to work Experimental, Numerical and Graphical Exercises illustrating the Subject," and contains a wealth of material sufficient to equip a student in engineering with as ample and practical a store of knowledge as most would have time to appropriate. The style and arrangement are, like the subject-matter, excellent.

W. B.

5. *Fifty-second Annual Report of the Director of the Astronomical Observatory of Harvard College for the year ending September* 30, 1897; by EDWARD C. PICKERING.—The Report of Professor Pickering just issued gives a summary of the work done at Cambridge with the various observatory instruments; also of the photographs taken under the Henry Draper memorial, which have led, for example, to the discovery of 17 new variable stars; of the work at the station at Arequipa, Peru, and that at the Blue Hill Observatory.

6. *Ostwald's Klassiker der exakten Wissenschaften*, Leipzig, 1897 (Wilhelm Engelmann). Recent publications of this valuable series include the following:

Nos. 88, 89. Krystallometrie oder Krystallonomie und Krystallographie. Von Johann Friedrich Christian Hessell. (1830.) Erstes Bändchen. 192 pp. Zweites Bändchen, 165 pp.

No. 90. Abhandlung über die Systeme von regelmässig auf einer Ebene oder im Raum vertheilten Punkten. Von A. Bravais (1848). 1897. 142 pp.

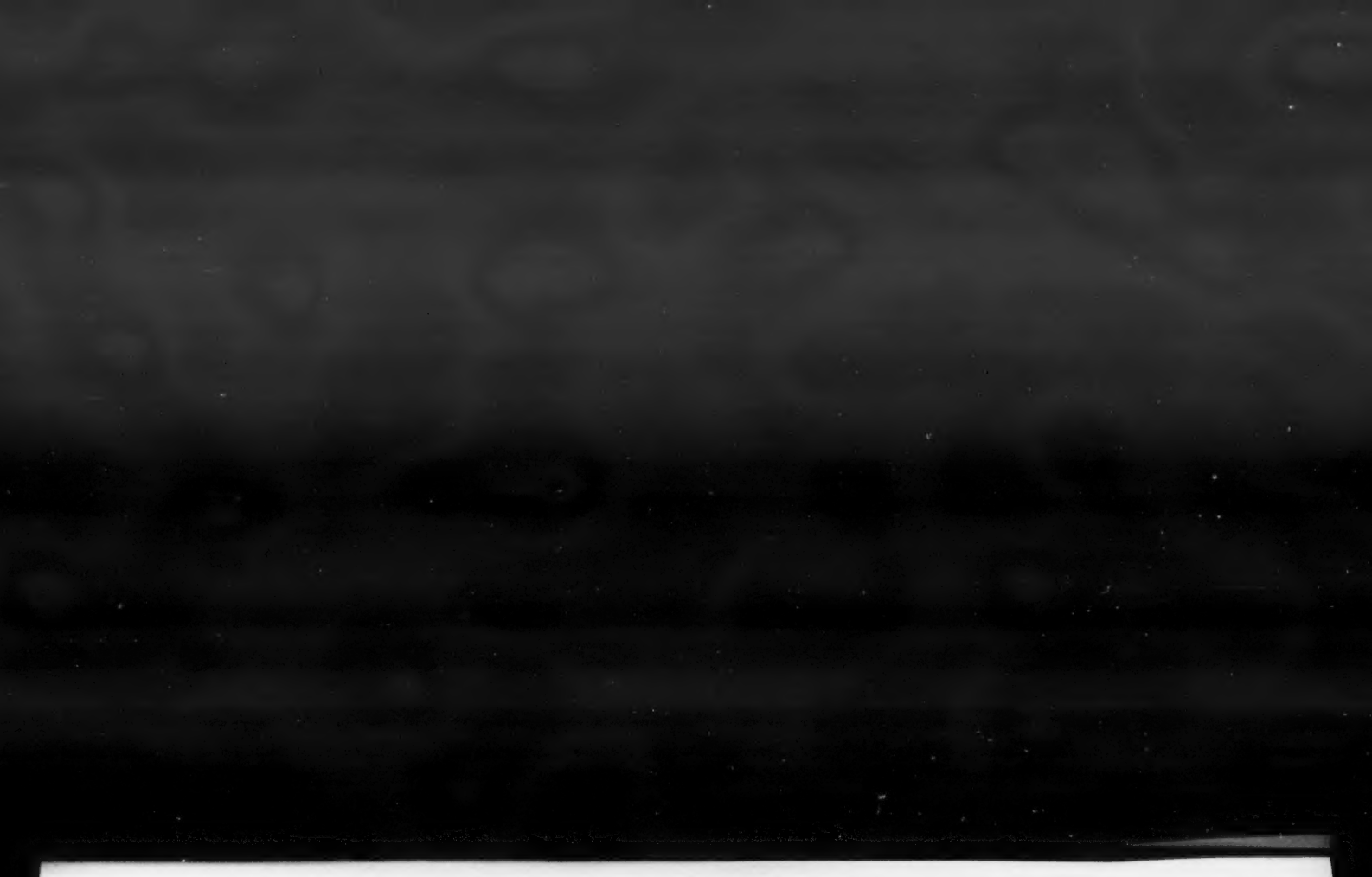
No. 91. Untersuchungen über verschiedene Anwendungen der Infinitesimalanalysis auf die Zahlentheorie. Von G. Lejeune Dirichlet. (1839–1840.) 1897. 128 pp.

No. 92. Ueber den natürlichen Zusammenhang der organischen mit den unorganischen Verbindungen, etc. Von H. Kolbe (1859.) 1897. 42 pp.

Science Readers, by Vincent T. Musché. Revised and adapted for use in schools, with a preface by Mrs. L. L. W. Wilson, Ph.D., Philadelphia Normal School. Book I, 127 pp. Book II, 128 pp. Book III, 176 pp. Book IV, 216 pp. New York. 1897 (The Macmillan Company).

La Vie, mode de mouvement, Essai d'une théorie physique des phénomènes vitaux, par E. Préaubert, professeur au Lycée d'Angers. Paris, 1897 (Félix Alcan).

OBITUARY.

PROFESSOR WINNECKE, the distinguished astronomer, died at Bonn, on Dec. 3, 1897.

REV. SAMUEL HAUGHTON, D.D. of Dublin died on October 31, 1897. He was a man of keen, original mind and his scientific writings include a wide range of topics in Mathematics, Geology, Physical Geography as well as in his own department of medicine.